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FARADAY'S DIARY

VOL. III

MICHAEL FARADAY

From the portrait by H. W. Pickersgill, R.A., presented to the Royal Institution by the artist, 1831

FARADAY'S DIARY

Being the Various Philosophical Notes of Experimental Investigation

made by
MICHAEL FARADAY
D.C.L., F.R.S.
during the years 1820–1862
and bequeathed by him to the
ROYAL INSTITUTION OF GREAT BRITAIN
Now, by order of the Managers,
printed and published for the first time,
under the editorial supervision of
THOMAS MARTIN, M.Sc.

with a Foreword by
SIR WILLIAM H. BRAGG, O.M., K.B.E., F.R.S.
Director of the Laboratory of the
Royal Institution

VOL. III
MAY 26, 1836–NOV. 9, 1839

LONDON
G. BELL AND SONS, LTD
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PRINTED IN GREAT BRITAIN BY W. LEWIS, M.A., AT THE UNIVERSITY PRESS, CAMBRIDGE

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Experimental Researches in Electricity

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FOLIO VOLUME III
OF MANUSCRIPT
(CONTINUED)

3026. Have been making a few experiments this morning in relation to Professor Schœnbein's (of Basle) letter to me on the relation of Iron to Nitric acid and other metals, etc. The following is a summary of part of the facts.

3027. Using N.A. of S.G. 1·3 or 1·35, if a piece of clean iron wire is put in, there will probably be strong action, but on touching the iron with a piece of platina also dipping in the acid, the action quickly stops and the iron remains bright and unacted upon. The preserving power of platina is very distinct.

3028. Still, iron wire put into such N.A., though acted on at first, will often cease to act and then become bright and remains unchanged as if touched by platina. This should not be done in a shallow vessel as a dish, but a deep narrow one as a tube.

3029. Another piece of iron wire immersed alone will generally be acted upon, but if connected first with platina, or with iron wire quiescent in the N.A., and then introduced, it will not be acted on. The second piece brought into this state may be used to protect a third and that a fourth, etc.

3030. If a piece of common iron wire dipped into the acid and acting, *then* be put in contact with the quiescent Iron wire, the latter does not protect the former, but on the contrary, loses its state and becomes common acting iron.

3031. Wished to know what currents occurred at such times and what relation such iron had to other metals: also what other metals would have the same effect as platina on it.

3032. First took a Galvanometer and then, with a piece of Zinc and a piece of platina, noted the position of the needle, which of course is noting the direction of the current. In the rest of these notes I will compare the action of the iron to either that of the Zinc or the platina—these being standards of direction and power.

3033. Common iron connected by Galvanometer wire with Platina and then both immersed in the N.A. is at the first moments as *zinc* to the platina.

3034. If iron action goes on in the acid, the metal continues as *zinc* to the platina and the current is very strong.

3035. When the platina has stopped the action on the iron, then the current is also stopped or rather ceases and the iron is to the platina what *platina* would be to platina.

3036. If iron taken out of acid and held in the air until action on it of the adhering acid commences, then on its reimmersion in the N. A. it acts as zinc, but the moment the action on it stops the electric current stops also.

3037. When an inactive iron in the N. A. is touched in the acid by another fresh iron which acts, the latter sets the first in action also. But at the moment of contact (through the Galvanometer or otherwise) the first is as *platina* (strong) to the second. When both are acting then there is no current.

3038. If whilst the two last irons connected by the Galvanometer are active in the acid, either the one or the other is touched directly by a piece of platina in the N. A., then action of both is stopped, but still there is no current. The stopping or protecting action of platina is very striking.

3039. If iron be brought into a quiescent state by N. A. in a tube *without* the use of platina, it has the same relations as if platina were used. If in with fresh iron and there is action on latter at first moment, then there is a current and the prepared iron is as *platina* for the instant, but action immediately supervenes on it. If in with fresh Iron and there be no action on the latter, then there is no current. Iron rendered quiescent by itself in N. A. is then as platina to platina and there is no current.

3040. Gold has the same power over iron as platina has and the same habitudes and relations.

If the iron and the plat. or gold both be put into the Acid first and *then* connected, there is very powerful current at the first moment.

3041. Even silver will do the same thing with Iron as Gold and platina, but then a changing doubtful action comes on; for at some moments silver is as platina to the Iron and at others the iron is as platina to the silver and the currents are often rapidly reversed.

3042. When Iron is rendered inactive in N. A. and is then connected with Silver in N. A.—it acts as platina to the silver, and the silver tarnishes, and the current continues.

3043. When Silver stops Iron action in N. A., the current continues in the new order, i.e. the iron continues to act as platina.

3044. Copper acts in the same way, for it affects the action of iron and the final current when steadied is as if the Iron were platina.

3045. Very curious shoots of action came over the iron sometimes, especially when it was in association with silver, etc.

27 MAY 1836.

3046. Have re-examined the relation of copper to iron. It does not seem to affect its state and action. The constant current shews that the copper acts as platina—the iron as zinc—must be some mistake above.

3047. Iron and silver. When each are employed in the ordinary state, there is immediate action and a current, the silver being as platina—then the current suddenly changes and the iron acts as platina—then another change and silver is as platina—immediately after, the iron is again as platina and this will go on changing more or less frequently, until at last there is a constant current, the *iron* being as platina. This very curious and shews first silver action in stopping iron force, then reversion, as silver attracts oxygen and sends hydrogen to the iron, then renewal of the action of the iron and its assumption of the peculiar state, and so on.

3048. Made a mixture of equal parts sol. nit. copper and nitric acid. If ordinary iron put in, action and precipitation of copper. If inactive iron put in, a precipitation of the copper takes place and action generally goes on on the iron. If inactive iron in N. A. be first put into contact with platina, and then both transferred at once to the acid nit. of copper from the strong N. A. and kept so a while, the iron can be so treated as not to precipitate the copper or any action on the acid, and by care even the platina may be removed, leaving the iron alone and unable to act on the acid or precipitate the copper solution. Generally however, after a short time it starts into action, begins to precipitate copper and is corroded rapidly.

3049. A few more expts. on the Iron action.

3050. Supposing that the platina might take up more or less of that peculiar state which it assumes in association with zinc in dilute S. A., I tried platina which had stopped Iron and ordinary platina in the N. A. S. G. 1·35, but they were alike to each other.

3051. Iron rendered passive by platina was equally indifferent to that platina or to an ordinary piece.

3052. Iron oxidized in a flame, the same as platina to either of the former platina—no current.

3053. Iron heated so far from the end that though blue and yellow where heated, was not sensibly changed at the end, was still as platina to the platina. So that very thin film of oxide will do.

3054. If after iron is oxidized in flame a part of the surface be rubbed with sand paper—then on immersion in N. A. it is at the first moment as zinc to the platina.

3055. If at the place so oxidized a little be rubbed off and then the wire plunged into the N. A., the oxidized part protects the unoxidized part, as might be expected.

3056. Zinc is not protected by Platina in this N. A., but its action rather exalted.

3057. Iron with platina and also with silver in fuzed Nitrate of silver. There was no current or if sometimes a little, it was more often as if the Iron were platina to the silver as zinc.

3058. When the iron is thus introduced into fuzed Nitrate of silver, it oxidizes and even blues, as if it had been heated in the air, *exactly*. This a link in the chain of facts relating to the oxidizement.

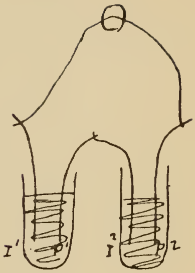
3059. The effect appears to be due to a superficial oxidizement or an association of oxygen and metal at the surface and is connected with the strength of the acid, etc. Oxidizement by heat must be a uniform and perfect superficial action and this looks very like the same.

3060. Consider it as due to a relation or affection of the surface just like the cases of affected platina. Ritter's explanation, Marianini, Daniell's, etc.

3061. Is related to my anomalous currents with Iron and the chloride and nitrate of silver.

3062. Is there any relation between it and the common mode of rusting? Preservation of Gun barrels when a continuous coat of oxide, by browning or bluing is put upon them.

3063. The action on the iron does not stop for want of conduction but want of chemical action, for on arranging two glasses with N.A. 1·35 thus, I^2 iron heated in flame and therefore oxidized, I^1 ordinary iron, P^1 and P^2 being ordinary platina–I^1 of course acted and on completing the circuit, there was a current with deflection of the needle, but gradually the current diminished and the action on I^1 also, and at last it stopped, I^1 having acquired the peculiar state.



3064. Then removed the oxidized Iron and made this prepared piece I^2, using again an ordinary piece at I^1; there was again action there and a current, but there was *no action* or solution of iron at I^2. It therefore conducted–it was not acted upon and the cessation of action when it and platina were alone in relation was due to the want of chemical action and not to the want of contact (metallic) or of conducting power.

3065. A series of three or four irons and platinas were put into action at once, all ordinary irons. There was a strong action and current; gradually the action ceased and the current fell off: some of the irons ceased to act, becoming bright in the acid; this again diminished the current and at last all the irons stopped. This was to be expected. Such a battery could not act.

3066. It is well that the electrolytic intensity of strong N.A. is so high that there is conducting power enough remaining, when there is no decomposition in one glass, to shew that going on in another.

3067. Heated a piece of iron wire so as to blue it all over and then put it into N.A. 1·35, so as to be altogether immersed. There was no iron in the acid dissolved. Bound another piece of iron wire in contact with a piece of platina wire, brought it into the peculiar state, and then put it into fresh pure N.A., leaving the platina in association with it. These two were left at about 1 o'clk.

3068. Iron wire soft with native ox. manganes[e]—no effect.
” ” „ oxide of tin
” ” „ oxide of Iron
” ” fuzed oxide anty. } no effect.
” ” „ oxide lead
” ” „ oxide bismuth
” ” scale of oxide of iron

3069. Iron wire with box wood charcoal is protected; the charcoal acts just like platina.

3070. Iron wire with plumbago; same result as with charcoal or platina.

3071. Rusty iron wire alone in N. A., acted on in the clean parts just like clean iron—the rust does not prevent the action. It is also affected by platina just as iron clean all over is affected.

3072. Rod of wrought iron $\frac{1}{4}$ inch thick in N. A. 1·35, easily protected by a plate of platina. It is even protected by a small wire of platina, provided the nitric acid be fresh, cold and contains but little nitrous acid. If acid warm or red then neither plate nor wire would protect the iron.

3073. Iron wire and platina in N. A., the iron quite under the surface, in a tube; applied heat carefully. Could raise the acid very nearly to the boiling point, yet the iron unaffected, undissolved and perfectly bright. Then it suddenly broke into *violent action* and the iron was very rapidly dissolved.

3074. Steel (the blade of a pen knife) made quite clean and put into the Nitric acid. At first strong action, Nitrous gas evolved, etc. but in a moment the surface covered with the carbonaceous deposit (black, etc.) and the action stopped.

3075. In its clean state the steel with platina produced a strong current of electricity (steel as zinc). As soon as it assumed the black quiescent state, it was almost indifferent to platina, scarcely any current occurring.

3076. When the platina and steel touched each other at first and then platina was first dipped in and afterwards the steel, the steel was protected like iron and did not even become black. This bright prepared steel acted as platina with platina, producing no current.

3077. When the end of the steel was black and peculiar, if the blade was further immersed, the black part protected the other from action, the latter remaining bright. So also black steel would protect bright steel or iron previously in communication with it.

3078. It appears to be the carbonaceous crust on the surface which protects the steel so quickly when introduced by itself.

3079. Cast iron—does not act easily on strong N.A.—but shews general results like those with soft iron. It is not however a good or regularly acting substance.

3080. Iron wire made the pos. electrode of a battery of ten pairs of plates, Wollaston's, in Nitric Acid, is quickly covered with a thick coat of black oxide of iron, which does not readily dissolve, and the action is nothing like that of the same iron in dilute or warm acid. No red fumes scarcely are evolved and oxygen apparently is set free at this Iron positive electrode. Obstruction to the action, which is considerable at first, soon comes on and when the iron is separated it is in the peculiar state.

13 JUNE 1836.

3081. With respect to the precipitation of metals by Iron, silver ought for several reasons to be in a peculiar relation.

3082. Common clean iron in common aqueous solution of nitrate of silver—no sensible precipitation immediately or change of any kind. Left in until next day. On the 14th, very little change—a few spots coloured and minute crystals of silver here and there could be discovered by an eye glass, but the iron was clean and there was no obvious alteration. 16th June, as on the 14th, except that a distinct though minute bunch of crystals of silver on one end of the iron. 20 June—same state except that fillament of silver longer and curiously formed.

3083. Common iron and platina in ordinary aqueous solution of nitrate of silver. *No current* either at first or afterwards.

3084. Common iron alone in a solution of nitrate of silver to which a little acid had been added—no sensible direct chemical action. Common iron and platina in the same solution—a very feeble current for a moment, the iron being as zinc, and then all action and current ceased.

3085. Common iron in an aqueous solution of Nitrate of silver to which much more pure nitric acid had been added. There was direct action, the iron was covered with a coat of precipitated crystals of silver: the action on the iron ceased and the precipitation also, the silver then dissolved and the iron was left bright and in the peculiar state, unable to precipitate silver or be acted upon. It is very remarkable to see the silver rapidly dissolving in a solution which cannot touch the iron.

3086. Common iron and platina in the same acid solution; there was a strong electrical current whilst the iron acted, but as soon as that action ceased the current ceased also. The association of the platina evidently helped to bring the iron more quickly into the peculiar state.

3087. With still more Nitric acid in the solution of Nitrate of Silver, the same general results as the last were obtained.

3088. Now tried some other metals with Iron in the common aqueous solution of nitrate of silver.

3089. Iron and Palladium in common solution of nitrate of silver are as Platina and Platina to each other. No action and no current.

3090. Iron and copper in same solution. There was an electric current, the iron being as platina to the copper as zinc. It was so at first and it continued so and even crystals of silver were thrown down upon the iron because of the current through it. In this experiment the copper threw down silver upon itself plentifully and to a far greater amount than upon the iron. The main part of the action is in fact local to the copper, only a little being transmitted through the iron. At first it seems strange that the iron should not resume its ordinary state, as it is the negative electrode to a current and a deoxidizing agency might be assumed on its surface. But in fact it is probably the crystals of silver on the iron which are the negative electrodes to the current which the copper forms and at the same time, by local action with the iron itself, they preserve it in the peculiar condition. In fact there is probably no current through the surface of the iron itself to the electrolyte, but only through it to the silver crystals and then to the solution.

3091. *Iron* and *lead* in sol. nitrate of silver. Iron is as platina to the lead as zinc. Crystals of silver appear on the Iron and the current is continuous for the reasons given above.

3092. *Iron* and *Tin* in solution of Nitrate of Silver: the Iron is as platina to the tin—crystals of silver form on it and the current is continuous as before.

3093. *Iron and Zinc* in solution Nitrate of silver. The same kind of results but more powerful.

3094. Now just compared some of these metals in dilute Sulphuric acid. i. *Iron and platina* were as they ought to be, a strong current and iron as zinc. iv. *Iron and lead*: at the first moment a weak current with the lead as zinc, but this instantly fell and no sensible current remained. ii. *Iron and Copper*. Current constant and iron strongly as zinc to the copper as platina. iii. *Iron and Tin*: at first a feeble current, the iron being as zinc to the tin, but after a moment the action was scarcely sensible. v. *Iron and Zinc*: a strong constant current, the Iron being as platina to the zinc.

3095. Ordinary iron and silver in Nitric acid S. G. 1·3. The iron acted at first moment strongly as zinc—very soon the current changed, and the silver acted as zinc, the iron remaining quite bright. There were one or two short starts of action the other way, but on the whole there was a *continuing* current with the silver acting as zinc.

3096. Now used fuzed Nitrate of silver, with Iron and Platina. Obtained a pretty constant current with the platina [as] zinc to the iron as platina, but found this was a thermo electric current, and accorded with the current produced when the iron and platina were heated in contact. There was in fact no electrochemical current here. When Iron and silver were associated in the same way, there was also a thermo electric current but *no* electrochemical current.

3097. Now used a battery, and made Iron the positive electrode with 2, 3 or more pairs of plates—Platina being the other electrode and both in N. Acid S. G. 1·3.

3098. With 2 pr. plates, Iron evolves gas and becomes covered with black oxide, which when the iron is unconnected with the battery, does not easily dissolve in the N. Acid but remains for a long time. Still much of it will wipe off and it has not that compact hard state of the coat formed by oxidation through heat.

3099. When 3, 4 or more pr. of plates are used, the same result is obtained.

3100. When with 2 pr. of plates the iron is left in the N. A.

awhile, I find that part of it is really dissolved. The change in colour of the acid is not altogether due to the production of Nitrous acid, but is partly.

3101. Iron in the inactive and peculiar state put into some N. Acid S. G. 1·3, and set aside to see how long it will remain untouched. Next day, the 14th, there was no obvious change; the iron was clean but the acid was a little coloured as if some iron had been dissolved. 16th June, as it was on the 14th, iron bright—20 June, same state.

14 JUNE.

3102. The iron and platina in N. Acid (3067) of 30 May examd.: just as it was then—no appearance of change. 16 June, still the same—no signs of action. 20 June—same state.

3103. The oxidized iron in N. Acid (3067) of 30 May examined. The acid a little yellow. Blue tint of iron gone and replaced by a partial red and rusty tint. There has been a change but only a slight one—left it to go on. 16th, still the same. 20 June, same state.

3104. Common iron made Pos. electrode by 2 and 3 pairs of plates in N. Acid S. G. 1·3. Gas evolved during the time: when contact broken, that ceased, and the iron left covered with a black coat of oxide. This not very quickly dissolved by the N. A., not in an hour or two, and it now and then assumed in the acid the blue tinge of oxide by heat.

3105. When common iron is the N. Electrode, it acts strongly on the acid and is soon entirely dissolved. It is curious to see the P. pole preserve it and the N. pole cause its corrosion. So also a piece of iron in N. A. S. G. 1·3 is preserved when touched by *platina*, and is not and continued in action when touched by *zinc*, etc.

3106. When Nitro mur. acid is used, then all these peculiarities disappear. The iron acts strongly and always as zinc to the platina.

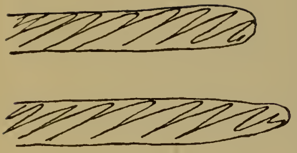
3107. Iron and platina with fuzed chloride of silver: the current produced is thermo electric, and the contrary to the true chemico-electric. The chemico-electric current cannot come on for want of contact until the iron is oxidized by the heat and then it is rather doubtful.

3108. On the 13th, two iron wires were made black in N.A. S.G. 1·3 by being rendered the Positive electrodes of a trough. They were then put aside in the acid. To-day all the black coating of oxide had disappeared and the iron was clean and metallic but inactive. There was much oxidation, etc. of the part out of the acid above—still left to themselves.

17 JUNE 1836.

3109. Clean common iron, sol. Nitrate of copper—precipitated copper readily; in sol. Sul. copper—same result—in sol. Sul. silver (acid) precipitated silver readily—in sol. acetate silver—very little immediate action—but nothing particular and did not stay to follow our results.

21 JUNE 1836.



3110. Experimented on effect of hot current of air rising from the chimney of a charcoal furnace. Using ends of brass rods of about this size[1]. When these were connected with the Electrical machine and rendered *Positive*, I could easily obtain the glow on any of them by quick working, it sinking into brushes as the supply of Electricity was less.

3111. On placing the points over the current of hot air from the furnace, I could obtain the glow also, but there was an evident increased tendency to break into long ramifying brushes.

3112. Using air above 300° but not hot enough to char writing paper and placing two ends above thus*; when the hot air was turned away, the end of P had glow and end of N dark—but when hot air ascended, fine brushes and ramifications passed between the ends. Was the same if A was made neg. by machine and B positive by contact with the earth.

3113. Hot air decidedly tends to make glow break into brushes. It may be from expansion only, but I think the heat goes for something.

3114†. Have had an apparatus made for passage of sparks, brushes, glow, etc. between wire ends in differt. gases. A, Glass globe inches in diameter. B and C, brass rods sliding in stuffing boxes, air tight, with rounded ends inside, about this size[1]: D, a cap and stop cock to exhaust. The glass of the Globe was thin but good and it bore exhaustion well and was very tight.

3115. By connecting B with the Pos. conductor of Machine and C with the ground, I could obtain the sparks, brushes and glow very well on the ends within, in common air at common pressures.

3116. Reduced pressure of *air* within to 20 inches mercury and ends being about 3 inches apart, found the brushes and the glow to come on sooner than when pressure one atmosphere, i.e. less electricity from the machine produced them, but still glow re-

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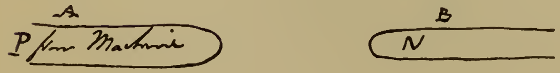
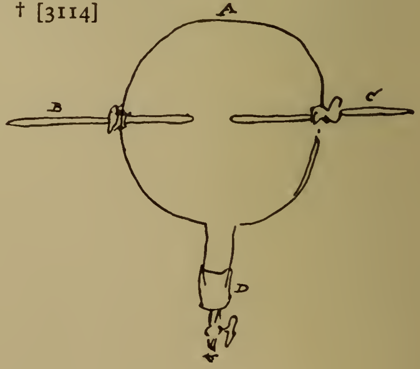
[1] The diagram is reduced to $\frac{3}{4}$ scale.

* [3112]



† [3114]



quired most as before. The brushes and ramifications were very good.

3117. It would seem as if the glass surface charged, for the branches would tend towards it in places and then cease, and the hand approached only on the outside could deflect them. Again, when machine worked slowly, the P. and N. ends would alternate in their action, as if glass came in intermediately between them, taking a charge and losing it alternately.

3118. Left the distance still about 3 inches and the wire A Pos. from machine but reduced pressure of *air* within to 10 inches of mercury. Discharge through this rarefied air more free than before, for now only short sparks could be obtained from conductor of machine. The ramifications were now very separate and large—each broad and purple, like the blue light of discharge in vacuo; they spread much into the capacity of the globe, and the character of the branches at the N. end approached considerably to that of those at the P. end. This was when the ball of the machine conductor was at a little distance from the conductor connected with the A wire, so that the electricity passed there as sparks, though as branches within the globe.

3119. When the ball without was close to A conductor so as to have a continuous current from machine, then there was an excellent dense brush between the ends in the rarefied air—continuous to common observation, but resolvable into successive discharges when the eye passed rapidly across it. Now could not bring on the *glow* to P. end however hard the machine was worked—by letting in a little air, it suddenly came on and then found the pressure 15 inches within.

3120. It was evident that rarefying the air, at the same time that it facilitated the discharge, tended to cause *brush* rather than *glow* and that condensing the air recaused glow on P. and retarded discharge. It was also evident that rarefying the air tended much to develope and spread out the ramifications of the brush and it appeared as if the N. brush was more extensively affected than the P. brush in this way.

3121. There are many changes in the order of the phenomena besides those dependant upon the rarefaction of the air only. The distance of the ends from each other makes a great difference, also their nearness to the sides of the glass or their projection into the space within. But the following was the order when the ends were retained about 3 inches apart—the E. current was continuous and constant and the pressure within, being first at 30 inches, was gradually diminished, as far as a good air pump would carry it. The end of A was pos. from machine and B connected with a discharging train. First *glow* at P. end—short brush at N. end. Then P. glow broke into a brush which gradually enlarged and the ramifications became very fine, long and separate and of a purple colour. Then these branches contracted together towards the line joining the two ends, becomes more straight and luminous as they coalesced and became at last a stream from one end to the other, narrow, hazy—having a little flexure and serpentining twisting—with now and then a long narrow twisting branch darting off to the sides of the glass and at the same time the whole body of the P. wire within began to glow, being covered with a beautiful light extending the twentieth of an inch above its surface. Then the stream of light between the two ends separated in the middle and retracted towards P and N, forming two brushes which became very luminous and strong. By degrees these brushes increased in size and brightness and at last joined, forming a brilliant communication*, and now even the N. wire luminous all over within, nearly up to the part close to the glass. This the highest degree of exhaustion I could procure.

3122. When the conductor at the machine was separated a little so as to make the Electricity a *spark current*, in this exhausted state of the globe, the light within was exceedingly beautiful but still of same kind, the difference being that now more electricity passed at once, but the effect was intermitting. In this way a machine may be made to give indications of what a more powerful machine could do.

3123. The ends of the wires were now placed within an inch of each other—the current at the conductor rendered continuous and the exhaustion again carried up from pressure of 30 inches within to as little as the pump could leave. First there were bright sparks within—then glow for a little while on the P. end—then brushes, which gradually became a purple stream of haze between the two ends, and the discharge appeared to be almost entirely

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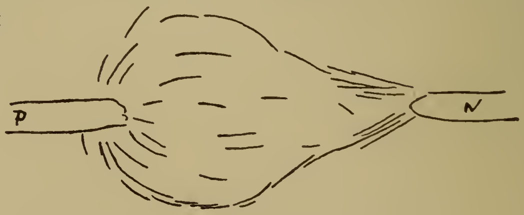
* [3121]



between the two ends directly—for there was no production of branches into the space around—nor any luminous haze on the back part of the wire, either P. or N. The nearness of the wires had induced this short course.

3124. It is of course understood that rarefying the air *always* facilitated the discharge through it.

3125. Now made the wire ends *two inches* apart and went through the same exhaustion, etc. At first brushes, no sparks—brushes fine—enlarge—branches well separated—now curving beautifully—then going to the glass—then an apparently continuous stream of purple light across from end to end, beautiful but contracted and straight. This very beautiful, [as] if the electricity passed in a *spark stream* at the conductor.

3126. By increasing the distance of the wires could make this stream open out into the wide capacious light before described, and then even a glow against the surface of the glass within.

3127. Now made some general observations. Thus when the wires were *four inches apart*, the ramification part of the series of effects was very fine because of the higher charge of the ends of the wires and the greater mass of air or space to pass through. The glow appeared on ends of wires and retrograded back towards glass beautifully; this glow is a consequence of discharge from the surface of the wire through the great body of air or space and not merely at the ends. With the utmost exhaustion the effect good—the light at the wires nearly joining each other, and indeed quite joining when the *spark current* was used instead of the continuous current.

3128. When the ends were very far apart, the stream, which came on after the brushes, did not join across the middle from wire to wire, but the discharge was in a great measure on the surface of the glass or near to it, and there was a haze of light on the whole inner surface of the globe. Each end of the wire also had a glow of light upon it.

3129. When the ends were farthest apart, namely equal to the diameter of the globe, then as the exhaustion proceeded there was first glow on P. end—brushes but few and contracted—these soon ceased with the ordinary working of the machine, and at last the discharge took place without any striking appearances and probably principally along the surface of the glass.

3130. It would appear that the glass has great influence either in facilitating the discharge between it and the rare air or actually upon its own surface. Surely it must be a joint action, for the body of the glass cannot be expected to conduct better. Must try a film of mica within the exhausted globe. Also a rod of shell-lac—also heavy Borate of lead glass—without alkali. Also a thread of silk.

3131. The glass also appears to be continually taking a charge and discharging again, probably with each independant elementary brush, rapid as they are in succession. It is even doubtful whether any case of discharge occurs positively continuous—for all seem to be resolvable into intermitting actions.

3132. When with the former distances the current was in *sparks* at the machine, then the effects were magnificent—the ramifications monstrous—and even when wires farthest apart, the light (stream) could be made to go quite across the interval.

3133. Evident that rare air can discharge electricity, not becoming luminous at the time, provided the intensity is not too high. As density increases, the conducting power diminishes, but every reason to believe that even at common pressure and temperature, air possesses the power and perhaps even at high pressures. Connect this with discharge from a large surface verily lowly charged, when under inductive action of a point at a distance opposite to it.

3134. Brought the ends within an inch—rarefyed the air very much—used constant stream of electricity and obtained the compressed continuous stream of light between the ends. But favourable as things were for a continuous discharge, even this light could be resolved by the moving eye into successive discharges—there was therefore always a charge of the two surfaces by induction before a discharge happened—and the discharge therefore always intermitting.

3135. An excellent mode of resolving a luminous dischge., where it is available, is to move the luminous end instead of the eye; thus a wire held in the hand opposite a charged conductor (in a dark room of course), if shaken will shew the point of light developed into intermitting actions, etc. This a good process.

3136. As variations are made from the continuous current to a current of small spark and so on to a current of large sparks at the conductor, a great variety of changes in the appearances of the discharge in the globe take place; these being in the same order when *all* other things are the same; but varying when the ends are more or less apart, the rarefaction more or less, etc. etc. Each element in the phenomena has its independant influence.

3137*. The ends within the globe were brought in contact—the globe exhausted thoroughly—and a continuous current at the conductor used. On opening the ends, gradually a peculiar and constant appearance of great beauty was observed. At the moment of separation, a glow of light came over the end of the *negative* wire, the positive being dark. As the distance increased, a purple stream or haze went right out from the end of the P. wire towards the N. end; this elongated as the distance increased, but there was *always* a dark space between the end of it and the haze on the N. wire. The space was nearly invariable in its width and also its position relative to the N. wire, nor did the glow on the N. end vary. It was curious to see the P. purple haze diminish or lengthen as the wires were separated: and the dark space is probably an important point to understand. Something like it often occurs in sparks taken in the air and is probably of the same nature.

3138. The light which occasionally overspread both wires always appeared to be due to the discharge of the electrified atmosphere on their surfaces. The passage of electricity in the rarest air is probably also in independant and successive acts or discharges.

3139. The effect of the *spark current* at the machine is simply an exaltation, for a moment, at intervals of time, of what occurs at each of the successive discharges when the continuous current is used. Hence for the moment shews what the effect of a much more powerful machine would be and is in that respect useful in exalting the effects.

3140. The phenomena vary with
Size of the ends.
Distance of ends apart.
P. or N. end primarily electrified.
Nearness of ends or wires to glass.
Size therefore of the vessel.

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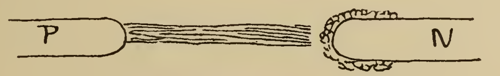
* [3137]



Nature of atmosphere within.
Degree of rarefaction.
Temperature of atmosphere.
Quantity of Electricity.
Substance of ends?
Mixture of atmospheres?

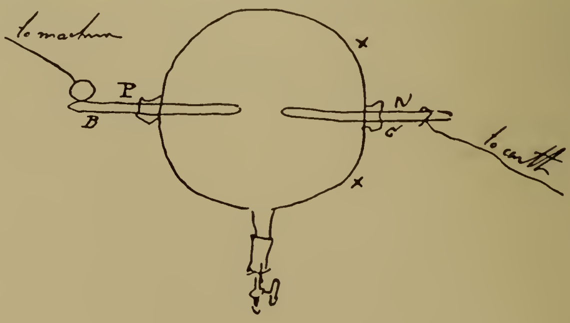
OXYGEN IN THE GLOBE.

3141*. Now made the atmosphere *oxygen* within the globe. The gas was very fair, and was passed into the exhausted vessel through a tube containing fuzed chloride of calcium to dry it. On beginning the experiment, the wire ends (being always the same in the experiments of this day) were about three quarters of an inch apart and the Electric *current continuous* at the machine. Sparks occurred at this distance in the globe and they were clear and bright and whiter I think than in common air of the same pressure. As the wires were separated, these sparks ceased, and there appeared a brushy star of light on each end, being so like each other that no evident difference appeared. When the ends were opened still wider apart, the same was the case. *Different in this to common air.* When the hand was applied against *x* or *x*, it induced brushes and ramification from the P. end and the spark at the N. end disappeared. But these brushes were nothing like so distinct and fine as those in *Air*: more like the N. brush in air, being short, close and not separating sensibly into distinct branches.

3142. When the ends were about $1\frac{1}{4}$ inch apart, the pressure being 30 inches and the electricity as *Spark current* at the machine, the discharge *in the globe* was not by sparks, but by two feeble brushes at the P. and N. ends, and these so like each other that the appearance would not decide which was positive and which negative. But putting the hand at *x* or *x* broke the P. brush into a larger brush as before and the N. brush disappeared.

3143. With the pressure and interval the same, the wire B was now made *Neg.* by contact with the rubber of the machine, the wire C being *Pos.* On using a *continuous current* there were imperfect brushes at the ends, very like to each other, and by applying the hand at *x* or *x*, obtained better brushes at the N. end and the P. brush or star passed away. Occasionally the brushes would become stars exactly like those obtained when B was Pos.

* [3141]



3144. When the Electricity was as spark current, then the two brushes at P and N wonderfully like each other and like what they were when B was *Pos.* Still very unlike what would occur in *Air*. Certainly there is a difference, whether B be made *Pos.* or *Neg.*, and when *Pos.* then approximation to ordinary appearance on P. and N. ends in Air is the greatest, but at all times very different.

OXYGEN IN THE GLOBE.

3145. Now prepared to observe effect of *rarefying* the *Oxygen*. Made B Pos. with constant current from machine—ends about $\frac{3}{4}$ inch apart giving sparks under common pressure. On exhausting a little, the P. end gave a decent brush, the N. end having little more than a fussy star—but still the P. end gave none of those fine ramifications which occurred in Air at the same rarefaction. Even when the Oxygen within equalled only 9 inches of mercury in pressure, still the brush from P was poor and feeble and scarcely any ramifications however the wires were opened out. When the wires were approximated until a spark passed, it was very feeble and of a yellow or gold colour. When a *spark current* was used, could then obtain ramifications at different distances of the wires in the oxygen thus rarefied: they were fine in form—they tended to pass as spark in the roots of their courses—and had not the purple hue of those in air.

3146. Now made B *Neg.* from the Machine, the current being continuous and the elasticity of the oxygen still equal to 9 inches of mercury. Then there was a very short brush at N. and the *glow* at the P. extremity. When the *current was in sparks*, both P and N had brushes—not much different from before. When the spark passed at short distances, it was of a golden colour, but blue in contact with the brass ends.

3147. Reduced the pressure of the Oxygen to 5 inches—made B *Pos.* from machine and used constant or *continuous current*—obtained feeble brushy and similar stars at both ends. The *spark current* gave a luminous stream across from end to end, but not so purple nor nearly so bright as that in Air similarly exhausted or rarefied.

3148. Continued to rarefy and the differences and appearances were generally the same. When the ends were wide apart and a *spark current* was used, ramifications were obtained, but nothing like those in Air.

OXYGEN IN THE GLOBE.

3149. As the rarefaction became more complete, the appearance became in form more like that in exhausted air, still with a great difference; thus with spark current there was a purple stream from end to end, but yet strikingly beneath that in *Air* similarly rarefied.

3150. Finally let in common air until the tension within was equal to 10 inches of mercury. But now obtained beautiful ramifications quite unlike those of the similarly rarefied oxygen.

HYDROGEN IN GLOBE.

3151. Prepared hydrogen from Zinc and diluted sulphuric acid over water—let it stand 3 hours. Exhausted the globe—filled it with the hydrogen, passing it slowly through the chloride of calcium drying tube—exhausted it again and refilled it with hydrogen in the same manner.

3152. Began at common pressure = 30·1 inches mercury, with a continuous current, the wire B *pos.* from the machine and ends about $\frac{3}{4}$ of an inch apart. Sometimes a spark passed and sometimes the discharge was in a hazy stream of light—but the *spark* was of a *beautiful crimson light*, and the haze (perhaps in part by contrast with it) was of a *grayish green.*

3153. A wider interval and *continuous current* gave brushes at P and N but the P. brush was the largest, the N. brush having something of its short compressed character when in air. The distance being increased, a better brush on both was obtained and, with the hand applied at *x*, the N. brush disappeared and the P. brush became large and good. By adjusting the distance and working the machine hard I could easily obtain the *glow* at P, having at the same time a little brush at N.

3154. With a *spark current* at the conductor, I obtained good large brushes and ramifications in the globe, the P. end giving the best. When the ends were far apart the ramifications were good but not purple as those in the Air; they were much paler and duller and of a greenish or grayish hue. Hence actual levity of hydrogen not do the same as exhaustion of air, for the latter would have increased the brightness of the ramifications in it whereas here they are less.

3155. The end B was then rendered Neg. by the machine, the pressure being still 30 inches mercury and the *current continuous.* Could now hardly get a spark to pass between the wires at any distance and in this respect different to *Air* or *oxygen*, but when it did pass it was *crimson*. At short distances the discharge generally produced a stream of pale hazy light, nothing like so purple as in air, quite different. When the ends were at some distance, there was a brush both at the *Negative* and the *Pos.* ends and I could develope the N. brush well. But on the whole the P. brush is most easily formed in this gas. With a *Spark current* easily obtained good ramifications, but always paler than those in Air.

HYDROGEN IN GLOBE.

3156. Now rarefied the *hydrogen*, taking it to elasticity equal 20 inches mercury within. The wire B rendered *Pos.*—the distance apart about 2 inches and the *current continuous*. There was a good brush at the P. end joining on to the N. end, and by touching the glass at x or x, could make the brush at P a *glow* and render N dark. On using *spark current*, there were fine ramifications or streams of light across, according to the nearness of the ends. The ramifications were still pale to those in *Air* and the spark when it did pass was red.

3157. Rendered B *Neg.* from the machine—the pressure within being still 20 inches mercury. The brush was best at the P. end, though much brush at and about N.: but it was not resolvable into good distinct ramifications like a good P. brush. The tint of the haze and ramifications were still to me of a grayish green hue—not purple.

3158. Made elasticity within only 10 inches mercury—the end B being *Pos.* and the *current continuous*. There was but little light: often the glow at P and nothing at N. Stream across frequent. With a *spark current* obtained ramifications, but these were of a pale soft velvetty character; though good in form and size. It was difficult to obtain a spark in this rare medium, but when it occurred it was also red or crimson.

3159. Rarefied the hydrogen much. The appearances as to the *form* of the brush, stream or haze became like those in rarefied Air or Oxygen. But when the whole globe was filled at last with the hazy light, both between the ends and against the glass and especially in the short bright brushes on each end; the colour of the light was still the grayish green—not the purple.

3160. *Common Air* was then let into the globe and again at once

HYDROGEN IN GLOBE. exhausted, so as to have it as rare as the hydrogen was just before. The light of the discharge stream was now that fine purple well known, and being dissected by the prism gave plenty of purple, red and other colours. It was also decidedly *more luminous* than the light in hydrogen when equally rarefied. *Much more luminous.*

AZOTE IN GLOBE. 3161. *Azote.* Obtained this gas by burning phosphorus in excess in air—left it to stand over water for some hours and then passed it through the tube with fuzed chloride of calcium into the exhausted globe.

3162. Began at pressure within of 30·1 inches of mercury—continuous current—B *Pos.* by machine and interval about $\frac{3}{4}$ of inch. Easily obtained sparks in the globe—these were very bright and beautiful—purple or blue and very sonorous—those in the *hydrogen* had been very indistinct in sound. At a greater distance, the glow came on P. end—the N. end being invisible. Using the *spark current*, very fine brushes were obtained, these being based on the P. end, but occasionally abutting as before on the N. end. By applying the hand on the outside, these could be enlarged and drawn to all parts of the globe within. It is very evident that the glass of the globe is with this atmosphere at least continually acquiring charges and in that way the form of the light is much affected, whether the pressure be ordinary or very rare. The character of the brushes and ramifications in this gas is that they are purple—very luminous by comparison—easily formed and well formed—more readily at the P. than the N. and that both ramifications and bright sparks could be easily produced under ordinary circumstances.

3162[1]. Made B *Neg.* from the machine and used a constant current. *Easily* obtained sparks inside (*not so with Oxygen nor hydrogen*) and these bright and beautiful as usual. On increasing the distance, obtained the glow on the P. end (being P. by induction only), and also brushes. On using *spark current* could also easily obtain brushes from the N. end, large and distinct. Still the brush power of P. end evidently superior. On touching glass at *x* with the hand could affect the N. brushes, making them larger and altering their direction.

3163. In many of these experiments, having *spark current* prevented sparks in the globe when they would have happened with a continuous current. A spark current usually produced streams and brushes within.

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[1] 3162 is repeated in the MS.

AZOTE IN GLOBE.

3164. Rarefied the *Azote* to force within of 20 inches of mercury, making B *Pos.* Ramifications good. Glow upon P. end good. Appearances much as in common air at same degree. Certainly Azote excells in the facility of producing long distinct ramifications, especially from the P. end and also in giving there a good glow. Light purple and beautiful.

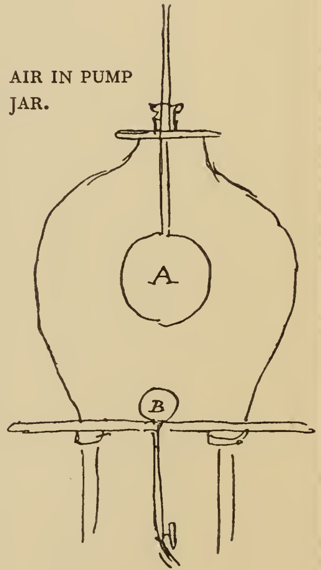
3165. Rarefied to the utmost and obtained the expected result—light beautifully purple.

3166. With all the gases tried, as the exhaustion or rarefaction goes on, the brushes existing at tension of 10 or 8 inches or less, begin to draw in towards each other—then form a stream across—then a lateral stream shoots out towards the glass or into the space—these become thick, fussy and soft in appearance and at last change into the full glow. This glow is in perfection when sparks are passing at the machine and conductor.

25 JUNE 1836.

AIR IN PUMP JAR.

3167. Experimented on Variations of Electricity—pressure—distance—and current in an air pump jar of this form and state. The ball A was at the end of an air tight sliding wire and $2\frac{1}{2}$ inches diameter. The ball B resting on the middle of the brass air pump plate was about $1\frac{1}{8}$ inch in diameter, but of course all the bottom area in the jar was metal. The ball A was always electrified either P. or N. from the machine and the ball B always in connection through the pump plate with a wire and the ground, i.e. with an excellent discharging system.



3168. Ball A made *Pos.*—pressure common or 29·6 inches—current constant at machine, had bright sparks within until distance about $2\frac{1}{2}$ inches, then no further discharge within, but brushes at the edge of the flat plate above in the air.

3169. Ball A made *Neg.*—sparks not so easily within as before but brushes at outside from edge of plate. These forms outside of course limit the accumulation within—and under same pressure without and within, prevent spark passing over more than a certain distance.

AIR IN PUMP JAR. 3170. The sparks obtained in either way when examined by a prism easily shew the black lines—they present all the colours of the rainbow I think—purple very rich, Red, Yellow, green, blue abundant.

3171. The spark current does no good *within* the jar in this state of the air. It only by increasing the whole obstruction to the passage tends to throw it off in brushes from the external conductors into the air.

3172. Large ball A made *Pos.*—continuous current—the distance of longest spark in air or 2¼ inches retained constant—but the *Pressure varied.* As pressure diminished the sparks, vivid and bright at first, became continually *paler* and also *quicker*, less passing at each spark. The sparks were at first very sonorous but also gradually became weaker in sound and of course the intensity without fell at same time and in the same proportion. When pressure within was 4·4 inches mercury the sparks suddenly ceased and the glow came on the P. ball over an area 2 inches in diameter, whilst the N. ball B was dark and no streams or visible appearances occurred between. Working the machine quickly, could change this glow into rapid pale purple sparks resembling a stream of light. These indeed very like the ramifications or brush in their character and state but not in their form.

3173. Went on exhausting to the utmost degree and found I could not change the glow and its stream into any higher or other form of discharge. Quick working of the E. Machine gave the stream continuous to the stationary eye, but the moving eye easily resolved it into successive discharges. Even the stream and glow could be obtained at once and then stream could be resolved whilst the glow appeared continuous. If the glow is an intermitting action, the intervals of time are vastly shorter than with the stream. The glow seems to be the most continuous phenomenon.

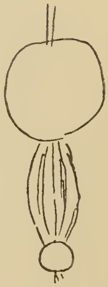
3174. The more the exhaustion, the more distinct and easily produced were the phenomena. The *N.* ball below at last glowed over a *small arc* and there was a dark space between that glow and the P. stream, about $\frac{1}{16}$ of inch wide. The N. ball glowed only when the P. stream descended to it. Pressure at last not more than 0·4 of an inch mercury and as little as the pump could make it.

3175. Large ball A made *Neg.*—distance the same, i.e. $2\frac{1}{4}$ inches—continuous current. At first only a small brush from a spot on the N. ball but when air rarefied to 23·6 inches mercury within, then bright spark passed—these continued, but as air more rarefied they became quicker and paler and more purple and at last were so quick as to look like a continuous stream, to the fixed eye, of considerable breadth ($\frac{3}{8}$ of inch), causing *no glow* on the P. ball below at any time, but sometimes a feeble glow on the upper N. ball having the dark interval between it and the luminous stream. AIR IN PUMP JAR.

3176. This purple stream was resoluble into successive discharges by the moving eye and its light by the prism gave plenty of red, orange, yellow, green (much) and violet rays.

3177. On gradually letting in air, the appearances returned through the series to the form of bright spark. At one time there was feeble divergence of the purple stream shewing the relation to brushes. The dark space near the N. ball gradually passed away as the pressure increased and sparks came on. The transition of sparks into ramifications, brushes, etc. here is exceedingly regular and distinct.

3178. Still same distance of $2\frac{1}{4}$ inches between A and B. Made A *Pos.* and used *spark current*; the sparks at the machine about 2 inches long—then gradually exhausted—at first no discharge within the jar, but when pressure within about 10 inches, purple ramifications occurred. Continuing to exhaust, these swelled out or appeared to do so, and by moving the eye could see that several were simultaneous and did thus diverge in their course. Continuing to exhaust, this became more extensive and each single ramification was thicker, paler and more woolly than before. On further exhaustion, these collapsed and formed one stream and this stream thickened until $\frac{1}{2}$ or $\frac{3}{4}$ of inch in diameter, and when air most rare, it gave a glow over the *Neg.* ball at each machine spark. Of course there was discharge within only when there was spark or discharge without.

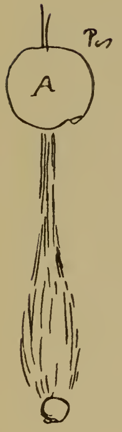


3179. Still same distance of $2\frac{1}{4}$ inches—ball A made *Neg.*—spark current. At first no spark within. On rarefying, sparks came on within—these became more and more quick, and pale, and then soon broke into extensive ramifications from the N. ball to the

AIR IN PUMP JAR. plate of the pump, in different parts and not to the P. ball on it. Further exhaustion made these collapse and they passed into a broad purple discharge from ball to ball—wide and hazy at outside, causing a glow over half the surface of the large *N.* ball and with the obscure space close to it.

3180. Ball A now *Pos.*—continuous current—rarefaction as much as it could be and constant, about 0·4 inches of mercury. *Distance of the balls varied.* On opening a small distance, *glow* came on N. and on P. ball and a dark space was between—the two glow[s] never coalesced or touched each other. Making the distance greater, the glow on N. continued as before, then there was the obscure or dark space and then a luminous stream commencing at P. ball. By very slow working of the E. machine, could separate as it were the successive discharges in the jar from each other and so make them come on separately and suddenly and then N. glow would cover half the ball for an instant and then, on making a discharge in form of a stream, contract to a constant smaller proportion.

3181. When the hand was put on the wire of the ball A on the outside still, if air well exhausted, there was the discharge and glow within though balls were $\frac{1}{4}$ of an inch apart, for that space appeared then to conduct as well as the body.



3182. When the distance was 2 *inches and more*, then the glow would cover the P. ball over half its surface and from it descended a stream of light easily resoluble by a moving eye into successive discharges. The stream was purple and descended very straight to the N. ball. On increasing the distance, the stream was also elongated, and when 6 or 7 inches long, it expanded and welled out at the lower part, becoming tinged and dimmer there, but the dark space close to the N. ball always existed.

3183. I tried the effect of a magnetic pole on this stream, but did not find it affected.

3184. Ball A now *Neg.*—continuous current—rarefaction as much as possible. Distance of balls gradually increased. There was stream of light straight from one ball to the other, having the obscure part near the N. ball—the stream was broader than when A was *Pos.* As the distance was increased, the stream widened much more than if A had been *Pos.*, but must remember that all the pump plate was *Pos.* When distance was 6 inches, the stream was very broad and pale and began to form sparks or branch roots at the negative ball, whilst at the *Pos.* ball a small surface of glow appeared.

AIR IN PUMP JAR.

3185. Ball A made *Pos.*—spark current—rarefaction as much as could be. Distance of balls gradually increasing. With *small spark current* and small distance, the N. ball below luminous all over each time the part of P. ball opposite also luminous and stream between. With *large spark current*, same effects and also bright sparks in the space between. When this bright spark within passed, then much less of the surface of the ball was luminous. In fact glow on ball shew that electricity passing there by air—when more of the electricity passed as spark, less would pass as glow—the sparks at the conductor (of the current) acted as measure of equal portions and so valuable in shewing how it was disposed of in passing. I could obtain the obscure place near the N. ball at pleasure.

3186. Using greater distances within, the stream was wider and somewhat paler. The N. ball was luminous each time, and the obscure place was close to it. By applying the hand against the outside of the jar at the upper part the P. ball could be covered all over with light—and also either very fine thin or broad conical ramifications from the ball A to the sides of the glass within be produced.

3187. Touching the brass cap (with Spark current) took away but little of the effect, for the space conducted as well as the body.

3188. Then A made *Neg.*—rarefaction great—spark current—*distance gradually increased.* With *small* spark and little distance, there was extensive glow each time over the N. ball—a little over the P. ball and some bright sparks there. Using *large spark* current, there was less glow but more bright spark between the balls within. On opening the balls out, then glow on balls good, but a coat of glow round the wire of A ball above towards the glass, and by clasping the glass with the hands on the outside could make this extensive. This effect shews that the non-luminous parts of the air are *conducting much* and also that glass charges, and apparently conducts in some way along its surface.

AIR IN PUMP JAR. 3189. The relation of this conducting surface and its conditions probably very important both to *induction* and *conduction.*

3190. On making the interval great, the luminous stream was very diffuse and wide; it was wider at the N. ball than the P. ball, being therefore of a pear shape inverted; this is probably because the base is the whole surface of the N. ball, and the Apex the upper part only of the P. ball. But then much electricity is passing to the plate of the pump invisibly at the P. side, though visible at the N. side or ball—hence also a reason for the shape of the visible part. On applying the hands to the glass, I could cause great divergence and disturbance of the rays—and the upper or any part of the *Neg.* ball A could be made to give out rays or conical diffuse brushes.

3191. Small or large sparks at machine varied the size of the streams, etc. and brought on sparks close to the metal balls, along with the luminous streams, etc.

28 JUNE 1836.

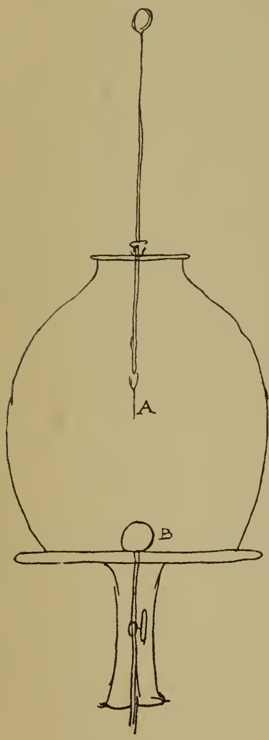
3192. Experiments on the discharge between points, etc. in *air* more or less rarefied and the luminous appearances produced.

3193. Barometer in Laboratory 30·13 inches.

3194. Air pump barometer. When mercury down in the tube, the distance of its surface from true 0° very nearly a just inch; taking into account capillary attraction it would be closely so. But when mercury raised to 30 inches on scale, the level in the cistern had fallen 0·31 of inch. As scale was of true inches, this quantity must be added to the apparent utmost exhaustion of the pump to give the true exhaustion. Thus when pump hole on plate closed by a stop cock, the pumps raised the mercury to 29·45 or 29·50, which, increased by 0·31, gave 29·81 inches or 0·32 of inch less than the barometer.

3195. Used the same jar, sliding wire and air pump as before; the Jar was 8 inches wide at the widest part and 11 inches high from pump plate to sliding wire plate. A was now a very fine needle point and B the ball of brass $1\frac{1}{4}$ inch in diameter as before.

3196. A *was rendered* Pos. *from Machine—continuous current at the conductor of machine was used—pressure that of the atmosphere*



30·13 *inches*, but distance of A and B varied. At very small distance, a feeble light on point A—none on ball B: very small sparks only could be taken from the conductor of machine. As the distance of A and B increased, the light on A remained apparently the same, but the spark at the conductor increased, because intensity was rising there. When distance from A to B 1½ inches—sparks half an inch long could be obtained on the outside conductor. When A 4 or 5 inches from B, there were good sparks at the outside conductor, and the inside of the jar was receiving, charging and discharging, as shewn by the ring of light at the bottom edge and by the effect of the hand on the outside. The light on A was a minute star—always apparently the same, and there was no light on B. AIR IN PUMP JAR.

3197. A *made* NEG.—*continuous current—pressure common—distance of* A *from* B *varied.* Results exactly as those just described, except that light of A *Neg.* much brighter than that which had appeared on A Pos. The first is probably a small intense *brush*—the latter a bright *glow*. The light of A thus *Neg.* appeared equal whatever the distance from A to B.

3198. A *made Pos.—spark or intermitting current—common pressure —distance of* A *and* B *varied*—first distance of point A from B made half an inch, whilst sparks at the machine were passed from 1 inch in length to smaller and at last to contact. At first sparks between A and B quite bright as between balls, these gradually became brushes from A and at last only a star or glow was there, although still small sparks at the conductor. In this case the air about the conductors charged etc. and acted as a regulator or fly wheel to the constant current at A point. On making distance between A and B greater still the same results were obtained, i.e. plenty of electricity and large spark at conductor gave bright sparks from A to B, smaller sparks gave brushes, and still smaller sparks only the glow. Of course as distance of A and B was increased, intensity at the conductor rose higher. The sparks also at the conductor, which passed bright and sharp in sound when they passed bright in the jar, were reduced into slower discharges of a ramifying or brushy character when only brushes or a glow occurred in the jar between A and B. AIR IN JAR.

3199. These phenomena useful illustrations of the action of induction in ordinary cases of charging surfaces in the Air. They connect also with the returning stroke.

3200. A (*point*) *made Neg.—spark current—common pressure—distance of* A *and* B *varied.* When distance of A (point) from B (ball) was $\frac{1}{8}$ inch, sparks at the conductor gave bright sparks from A to B—on diminishing the sparks at the conductor, the discharge within became a haze or stream from one to the other, with a little glow on the *Pos.* ball B. When A was half an inch from B and sparks at the conductor, being first long, were gradually diminished, then first bright sparks within—next straight purple stream resoluble by the eye—then glow or star on A, and glow on B. When distance from A to B was one inch and sparks at the conductor were diminished, there was first bright sparks between A and B, and then the glow. There were no purple streams across but now and then bits of brushes, representing in fact the rudiments of streams. When the distance from A to B was 3 or 4 inches, with diminishing sparks at the conductor, there was either an imperfect spark or else short brushes at A (the Neg. point), quickly diminishing to the star or glow. Now the glass began to receive and conduct visibly as in former case.

3201. In reference to this conducting power of glass must remember its damp surface—compare it with wax or resin.

3202. The brushes from A point Neg. in Air are very poor when compared to those from A *Pos.* under the same circumstances.

3203. Now proceeded to vary the condition of *pressure* or density of the Air, using the same point A and ball B as in the results just described. The same jar, etc. etc.

3204. A point *Pos.*—continuous current—distance of A from B an inch. At common pressure a star on A ( ). Proceeded to rarefy the Air, but no sensible difference except that intensity on the conductor fell until rarifaction was considerable and then the light crept up the needle backward from the glowing point until the needle and even the end of the sliding rod was covered with a glow, but the point was always the brightest.

3205. This effect shews very well that the star on the Pos. point and the glow on the sides of it and the rod are the same thing. Hence the star on a *Pos.* point is a *glow*, as might indeed be traced from the state of the glow on a round end made Pos. in open air.

3206. Still further exhaustion caused streams and brushes to pass apparently from Pos. point A to *Neg.* ball below. These were purple and good, and when the exhaustion was very great produced bright spots here and there on the Neg. ball. The streams were resoluble by the eye. AIR IN THE JAR.

3207. Made the distance from *Pos. A* to *Neg. B* four inches and then rarefied from common pressure. At first there was the star on A and the glass conducting, as shewn by the luminous ring round its contact with the pump plate ( ). When rarefaction considerable, this ring diminished in brightness—the star became brighter and the needle A glowed upon its surface—then ramifications passed from it through the air and at last successive direct discharges to the ball B, which becoming more and more numerous produced the same results as at the smaller distance of streams with bright sparks.

3208. *Made* A *point Neg.—continuous current—distance from* A *to* B *one inch—rarefaction gradually increased.* At first there was a feeble star on *Neg.* point A and a little glow on Pos. ball B at common pressure ( ). On rarefying, the glow on B disappeared—but the spark on A neg. point increased in light and at last extended distinctly out from the point a small way, being a very luminous small brush, yet so compact as to look like a solid spark. It gave no ramifications or decided brush with any degree of exhaustion, the distance being always only 1 inch. (By increasing the intensity of the electricity by using a spark at the conductor, this condition of discharge could be carried forward into a bright blue stream of light joining A and B ( )). AIR IN RECEIVER.

3209. Made distance greater, as 4, 5 or 6 inches, and then exhausted, beginning at common pressure. At first discharge from Neg. point A over surface of the glass. As rarefaction went on, ramifications went from Neg. point towards glass—then these diminished—the star on A point became brighter—a glow came over the Pos. ball B, and increased gradually in brightness, until it was at last very bright and also stood up like a low flame half an inch or more in height or thickness. On touching the sides of the jar, this flamy glow was affected—assuming a ring form, like a crown on the top of the ball B and revolved with a comparitively slow motion, i.e. about 4 or 5 times in a second.

AIR IN JAR. 3210. This effect appears to me due to the charge and discharge of the glass. Electricity is communicated from the *Neg.* point A to the glass, conducted downwards and discharged to the ball: this process of charging and discharging can be made, by a proper application of the hand to the outside of the glass (as passing it round), to go on in succession round the jar, and when once it has commenced that course it will continue though the hand be taken away and will be shewn by the consequent revolution of the flamy glow on the ball B beneath.

3211. This again relates to charge, induction, etc. etc. and is very beautiful in its appearance.

3212. Now made A *Pos.*—spark current—distance of A from B 1 inch. Rarefaction progressive. At first bright sparks between A and B (   ). As rarefaction proceeded these became dull purple and more numerous whilst the intensity on the conductor fell—then they became ramifications—these then contracted together and became a purple stream or brush across from A to B, with an *obscure* place near the Neg. ball B—finally with these last appearance a bright glow over one half the Neg. ball B and the obscure part next to it upon which abutted the purple stream belonging to the Pos. Point A.

3213. A *point* Pos.—*spark current—distance of* A *from* B *four inches—rarefaction progressive.* At common pressure no spark, but a star on A point, whilst B dark—the sides of glass jar were conducting, the edge on the pump plate being luminous. As rarefaction went on a few ramifications from A appeared, short in their extent—these increased in number, length and thickness and passed through the whole extent of the Jar—then they became thick and woolly—then the direct discharge between the point A and ball B increase[d] in light and efficacy and the lateral ramifying discharges diminished until all visible discharge was direct and straight between A and B. Then this stream expanded and swelled, and gradually as the rarefaction rose to the highest point, the *Neg.* ball B began to *glow.* At that moment the obscure place next to it appeared, and I doubt whether that obscurity ever appears except in association with the glow on the N. surface, which probably it always accompanies. Must watch this. Letting in air gave all these appearances in the reverse order.

3214. A *point* NEG.—*spark current—distance of* A *from* B *one inch —rarefaction progressive.* At common pressure a star on A pulsating with the sparks without. When the elasticity within was 20 inches mercury, the star at *Neg.* point A changed into bright sparks—as rarefaction went on these became more numerous and pale or purple—when rarefaction very high, these purple discharges became ramifications, which gradually passed into form of stream and a glow came over the whole of *neg.* needle A and also a part of the sliding rod above it. At this time, bright small sparks occurred on the P. ball B, where the stream abutted on it, and there was very little tension of Electricity on the conductor of the machine. AIR IN THE JAR.

3215. *Made point* A *Neg.—spark current—distance of* A *from* B 4 *or* 5 *inches or more—rarefaction progressive* commencing at common pressure. When spark passed at the conductor, there was a star on point A and the glass sides were charging and conducting, as shewn by light at the edge, on the pump plate. On rarefying, some ramifications proceeded from the *Neg. point* A (but nothing like so good as those proceeding from A made Pos.—still they are good to shew that ramifications are not essentially from pos. point or surface). Then the discharge took place directly from A to B in a stream, half purple, half bright spark, i.e. purple flashes mingled with sparks alternating, etc. etc.—finally at greatest exhaustion, there was a purple diffuse stream across, resoluble as all streams, brushes and ramifications are by a quick eye, and the Neg. point A was in a constant glow all over and up the sides of the needle and sliding wire.

3216. Now experimented with the same arrangement, i.e. A a needle point and B a brass ball on the pump plate—used also a continually rarefied atmosphere—but *varied the distance* between A and B.

3217. A *point* POS.—*continuous current—Rarefaction great—distance gradually increased.* At minute distance, had a rapid series of *bright* sparks—at a greater distance up to ¾ of an inch, had successive discharges by brushes or ramifications—then as distance increased these gradually ceased and a glow came over the point and sides of the point A Pos.—this continued until the distance was about 3 or 4 inches, and then ramifications again occurred

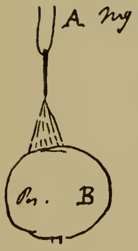
AIR IN THE JAR.

in a large, hazy, thick stream from A to B, and the discharges were now very separate. But it must be considered, that increase of distance had increased difficulty of transmission, and that hence both intermission in the passage and accumulation on the conductor—each ramification or separate discharge carried much electricity across. With these long stream ramifications had bright sparks each time on the surface of the Neg. ball B—but still there was a partial obscurity in the part of the stream just above the ball B.

3218. A *Neg.—continuous current—rarefaction great—distance gradually increased.* At first, a little star on Neg. point A—could not call it a bright spark though distance very small. On increasing the distance, the discharge was across in feeble streams, a star being on point A and some bright sparks on ball B. With larger distance, the star on Neg. point A was very good—sometimes when the electricity was abundant even a glow came over the end of needle A and then a glow would occur on the Pos. ball B in the following manner—a hazy stream would seem to form at and descend from A and, collapsing on B, would produce the glow there, for the stream only lasted until the glow on B was formed. When the distance between A and B was the greatest (about 6 inches), then branches went from the Neg. point A to the sides of the glass and were discharged over it.

3219. A made Pos.—spark current—rarefaction great—distance gradually increased. At the smallest distance, not a bright spark between A and B but a purplish star or spark at A or Pos. point and a fine glow all over the *Neg.* ball B, with bright sparks on the middle part opposite point A. Increasing the distance left the glow over B with the obscure space next to it, but the purple star or stream from A grew to an enormous size in length and width, continuing unchanged in its character, and at last began to go towards the glass sides of jar, discharging there as well as on to the ball. All this was good and beautiful.

3220. A made Neg.—spark current—rarefaction great—distance increasing. At minute distance, bright star or spark on Neg. point A and also on the opposite surface of the P. ball below, but purple stream or discharge *between.* When the distance was half an inch or more, there was the same purple stream to the ball B. At greater



distances the sparks outside were fewer and larger, because of the increased obstruction, but still the same purple stream from the Neg. point to the Pos. ball, or when distance still greater, the discharge constituted a direct purple haze—at last being very wide and expanding even towards the glass. On making the electric sparks more numerous and smaller, obtained a contraction of this haze, and by gradually diminishing the sparks until very minute, the haze gradually contracted to a star on the point A and the flame like glow on B (   ). By making the sparks a little larger, could easily make this star and glow pass into the stream reaching from A to B, the transition being very beautiful and gradual.

AIR IN JAR.

3221. Now made A *and* B *both points* of needles in the same apparatus and then went through the series of conditions as before.

3222. A *Pos.—constant current—common pressure—distance increased gradually.* At minute distance, a series of bright sparks, many short. When distance was a little more, there was a star on each point and a purple stream between. As the distance increased, the purple stream between points passed away, the star on the Pos. point A diminished much, whilst that on point B remained good and was considerably the best—(A star was probably a glow and B star a brush). The sides of the glass jar were now conducting.

3223. A *point Neg.—continuous current—common pressure—distance increased.* At minute distances there were bright sparks between the points A and B; this was not the case under the same circumstances, when B was a ball instead of a point. When the distance was $\frac{1}{8}$ of an inch, the discharge was from point to point in what might be either blue sparks or streams. At a greater distance, stars alike on both points and a little stream between. At greater distance, still stars alike and nothing visible between. At greatest distance, Neg. Point star on A the brightest—star on P. point B, smallest or feeblest, and the glass conducting electricity.

3224. A *point* Pos.—*spark current—common pressure—distance increased.* With constant spark at the machine, small distance of A and B gave bright sparks—large distance of A and B gave a star at B Neg. and star and brush at A Pos.—middle distance of

AIR IN JAR. A and B gave purple streams across, intermediate between brushy spark and brush. With a constant distance between A and B, small sparks at conductor gave stars on both A and B—larger spark gave good brush at A and star at B—and still larger sparks gave bright spark between A and B and sometimes a sparky brush.

3225. The spark here was not so long and good I think as when B was a ball instead of a point (   ), A being a point in both cases.

3226. A *made Neg. point—spark current—common pressure—distance increased.* With constant spark at the machine, small distance of A and B gave bright sparks—a little more distance of A and B gave stars on both with stream between—a little more distance gave stars alone. With constant distance of A from B, large sparks at machine gave sparks bright within between A and B—small sparks gave only stars on points A and B within—and a certain sized spark gave a feeble brush or stream between A and B at the same time with the stars. If the distance within were made greater, the machine would not even send sparks above a certain size to the conductor outside or even bright sparks at all. Too much power was wanted to produce them.

3227. Now used the points A and B, but varied the pressure. A *point Pos.—continuous discharge—distance constant, being* 1 *inch from point to point—rarefaction increasing.* At common pressure, stars on each point and no stream between. Rarefaction brightened both the stars, but the star on B neg. brightened most. Gradually the N. star on B became a very short bright brush about the $\frac{1}{30}$ or $\frac{1}{40}$ of an inch in extent, whilst the Star on A or Pos. point produced a glow on the sides of the needle above and a luminous stream gradually appeared between the two points. When the rarefaction very great, the *neg.* starry brush on B became bluer and gave origin to a glow spreading downrds. from the point over the needle. The Pos. Star on A became redder. The stream between A and B continues, but becomes brighter as the exhaustion is more perfect.

3228. As the Neg. glow spread down the needle B, I could not decidedly observe an obscure part but the purple stream was weak near the *Neg.* point B. Watched the change in the appearance as air was allowed to enter. In the most rarefied air, the stream could be easily resolved by the eye into successive discharges though they were quick, but as air entered and the stream passed into two stars on the points A and B, the luminous appearance of each ramification continued longer in the moving image obtained by a mirror, the intervening dark space became less and less until at last the star presented an unresolvable line of light in the moving mirror; the light in fact was sensibly continuous and of course the discharge so also. AIR IN JAR.

3229. A *point Pos.—continuous current—distance of* A *from* B, 4 *inches and constant—Rarefaction increasing*. With common pressure, had stars on both points—rarefying to the utmost, still the light continued as stars to the last—for streams across did not appear. But the stars brightened much during the exhaustion; that on *Pos. point* A was a glow over the extreme end or point of the needle and a short brush beyond it, looking *like a double star*. Whilst that on the *Neg. point* B was a short bright brush (not a glow) at the end of the point. I have no doubt these brushy stars intermitted though I could not resolve them.

3230. A *point Neg.—continuous current—distance from* A *to* B, 1 *inch—rarefaction progressive*. At common pressure, stars on both points—by rarefaction the stars became brighter but *never* obtained the brushes or streams across. Even to the last the stars were simple, but the negative one on A was the brightest and it projected slightly like a short dense brush. It could hardly be resolvable by the mirror into successive action; still there were darker parts in the line image, as if the action of discharge was intermitting.

3231. A *point Neg.—continuous current—distance between the points*, 4 *inches—rarefaction progressive*. Phenomena as just described. No stream across at any time—dense brushy star on N. point and glow star over P. point and its extremity—both brightening as the rarefaction increased, but the N. star most.

3232. A *point made Pos.—spark current—distance* 4 *inches between* A *and* B*—rarefaction increasing*. At common pressure and small spar[k]s at machine, stars on A and B—with larger sparks, brushes on A Pos. and star on B Neg. When Air more rare within, brushes were obtained more easily on A point Pos. and with large sparks these were very fine. As the air was rendered

AIR IN THE JAR. still more rare, these large brushes or ramifications collapsed into a direct stream between P. and N., i.e. A and B, which was resoluble by the eye into successive discharges. When very rare within, then a glow all over B Neg., the stream seeming to touch at the point and then spread over the whole of the needle. The effect was very good. The power of the Pos. point over the negative to produce brushes or ramifications in common air was here very distinct.

3233. A *point Neg.—spark current—distance between the points,* 4 *inches—rarefaction increased.* At common pressure, small or large sparks at machine gave only stars on A and B. With some degree of rarefaction, small sparks gave stars on the points A and B, larger sparks gave ramifications or even streams—or rising even to sparks. As the rarefaction increased, the ramifications became streams, a smaller spark then giving ramifications and a still smaller, stars on both points. When most exhausted, even a small spark would produce a purple stream and a large spark much brighter streams, the streams being also separable by the eye into successive discharges.

3234. Now using still both points A and B, varied the distance gradually. *Thus* A *made Pos.—continuous current—rarefaction great as could be—distance varied.* At small distances there was a glow on and down the Neg. point B and an obscure spark and stream mixed from Pos. point A. The latter separable by the eye. At a greater distance, the glow upon B or Neg. gradually drew towards the point and at last formed a dense short brush at the end. The purple stream at the same time diminished its alternations, becoming more and more rapid until it became a continuous glow upon the *Pos. point* A or even only a star there.

3235. A *Neg.—continuous current—rarefaction great—distance of* A *and* B *gradually increased.* There were stars at both points all the while. Now and then, whilst distance short, there was a stream across from A to B. The stars always resoluble from first to last. It was nothing like so easy to obtain streams or brushes now as when A point was made *Pos.*

3236. A *point Pos.—spark current—rarefaction great—distance of* A *from* B *varied.* When distance small, either small or large sparks gave stars on both points, and blue or purple stream between.

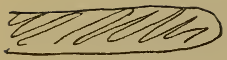
A larger distance gave also the blue stream across, but the Neg. point B was luminous all over its needle. The Pos. A had a small star occasionally. With a still larger interval, the stream within spread out and was very wide and diffuse. Smaller sparks then gave several distinct woolly ramifications. When the distance was greatest, the application of the hand to the outside of the Jar easily determined fine ramifications from the Pos. point A. AIR IN THE JAR.

3237. A *point neg.—spark current—rarefaction great—distance variable.* With small distance between the points A and B, the Neg. A was luminous all over its needle and blue streams proceeded from A to B. As the distance between A and B increased, the blue streams increased in size, became very large, and when large sparks were used at the conductor of machine, the hand applied to the sides of the glass could draw off large brushes from the general stream. As the distance increased also the glow upon the sides of the Neg. point or needle A went off, but often recurred again when a spark larger than usual passed at the conductor. There were no ramifications in this last state—but the form of the extended positive surface below not good for them.

3238. Experimented on the capability of resolving a brush, star or glow upon a point into successive discharges by making the point move before an oppositely charged conductor. Thus a metal point held in the hand (it ought to have been connected with the discharging train) was shaken to and fro quickly and the line of light appearing to the eye as produced by the moving star examined as to its continuous or interrupted nature. Whenever the light on the point was accompanied by sound, it could easily be resolved into successive actions, but the fine small spark on a fine point either Pos. or Neg. I could not resolve (but a stronger machine and a darker room might do it; perhaps, if a charged battery were in connection with the conductor, would be still better).

3239. I could not resolve even the glow on the round end of a rod made positive by induction. Still, extent of the luminous area would interfere with the resolution. The round end rendered Neg., when it was not sonorous, was not resoluble—though now and then I thought it was so. Must try again.

3240. The phenomena produced by passing ends before charged conductors very good—the discharge occurring in brushes, sparks, etc. The duration of each and the time which passes between the quick successive discharges are well shewn by the light and dark parts. Can thus separate the state of things before, at, and after a single corruscation exceedingly well.



3241. For similar surfaces, distances, charge, etc., Negative brushes are much smaller and much quicker recurrence than Positive brushes. The Neg. surface cannot apparently hold a charge against Air so high as the Pos. surface. Must deduce the consequences of this in theory and practice. Thus if two equal surfaces opposite to each other in Air, one Neg. and the other Pos. gave, the first many small brushes, and the second a few large ones, during the discharge between them, then what is the condition of the air, charged or not, between 2 successive brushes from the P. termination? and whilst several N. brushes must have been formed. Probably in such a case, the discharge brushes are simultaneous, or else the neighbouring parts of Air or objects around intervene as inducing agents, between the actions of P. and N.

3242. In *conduction*, must observe the increase of conducting power, if any, of hot distilled water over cold distilled water.

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LIGHT OF DISCHARGE THROUGH AIR.

3243. Luminous appearances of discharge or conduction through air in the order proceeding from the *least intense and most continuous discharge* to the *most intense and least continuous discharge*:

Obscurity or invisible discharge
Glow
Stream
Brush
Spark

These may all be considered as affections of the aerial medium, as probably are all the luminous appearances of electrical discharges, short of the ignition of the conducting bodies used; and the expressions are not meant to represent scientific distinctions, but only ordinarily recurring forms of the phenomena. The glow is probably the same affection of the air as the stream and the brush, but the first is continuous and of necessity near the con-

LIGHT OF DISCHARGE THROUGH AIR.

ductor, whilst the latter are intermitting and extended into space. The stream does not include all parts of the air or medium through which the electricity is being discharged; on the contrary, in rare atmosphere there is evidently much air in the obscure state, which is conducting and in the same condition as that close to the conductors when the whole discharge is without light. The spark, the brush and the stream are evidently connected, i.e. are in reality the same thing but more or less exalted; they pass by easy transitions one into another.

3244. *Size of ends* opposed to each other, with the appearances and nature of the discharge; beginning with points and enlarging these gradually to balls, etc.

Glow or star . . most continuous discharge
Ramifications
Brush
Sparking Brush
Spark . . . . most intermitting.

The denser the air the more distinct these effects; in rare air the order is the same, but the series seldom goes further than glow—stream (or ramification in one form). Size, by increasing the surface at which induction takes place, increases the quantity of Electricity discharged and hence the heightening of the character of the discharge. Though the intensity is greater on a point than on other parts of the surface of the conductor to which it belong, I do not think it is so great as on a ball charged enough to give a discharge at the same distance as the point.

3245. *Rarefaction of the Air* from common pressure or dense, to rare and most rare. The appearance and character of the discharge through it is then as follows:

Bright spark . . . most intermitting discharge
Purple spark
Brush or ramification
Stream
Glow . . . . . most continuous discharge

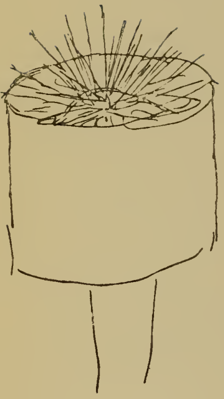
Rarefaction facilitates discharge through the elastic medium, and therefore lowers the intensity upon the conductor at the machine —lessens also of course the accumulation, and lessens the quantity passing at each intermittence. Rarefaction is equivalent in effect to pointing the ends of the conductors. If the intensity on the surfaces in the rarefied medium is not diminished (Harris) then it is evident that the quantity for a certain intensity is diminished. This may be because the quantity of aeriform matter in contact is diminished.

3246. *Distance of ends from each other*, i.e. of inducing surfaces from each other. As the distance increases the order of kind of discharge is as follows:

Sparks . . . . most intermitting discharge
Brushes or stream
Glow or star . . most uniform discharge.

Distance increases the resistance—increases therefore the charge which rises on the machine conductor—diminishes the effect of induction—diminishes the character of the luminous discharge.

4 JULY 1836.



3247. A discharger of points, being a cylinder of about an inch and a half in diameter, having one end terminated by a series of needles stuck into a cork, covered with tin foil so as to make complete contact. There were about sixty needles, the points outwards nearly equidistant and forming a sort of thistle head (2490).

3248. This discharged either positive or negative conductor of the machine very well. I could draw no spark on to it, unless when very near, nor when placed upon the Pos. or Neg. conductor did it give sparks with more facility than a single point would do.

3249. A discharging ball was placed within a certain distance of the Positive conductor so as to give sparks of a certain length; then the ball of points or a single point were approached so near as to cause the cessation of sparks. This took place at very nearly equal distances for the single point and the sixty points—the sixty points had a little the advantage. Hence, though the whole set of points was as good as the one, yet it is evident that any single point of the sixty was greatly interfered with by its neighbours and its power much lessened.

3250. When ball made Pos. by holding it opposite the Neg. conductor, there were very feeble straight short streams or brushes, with scarcely any noise, from many of the points nearest the conductor and opposite to it. When ball put on Pos. conductor and hand held opposite, the same effect.

3251. When the ball made Neg. either directly or by induction, then stars on many of the points at the same time.

3252. Ball of points made Pos.; much wind issued out directly from it. If smoke of green taper near whilst machine working, it was attracted first by ball of points and then repelled from it and attracted by the silk on the top of the revolving cylinder. If a little smoke were lodged in between the roots of the needles, and then the machine worked, it did not get out very soon, as if it were electrified by contact, but was gradually drawn out by the run of neighbouring air determined by the action of the points.

3253. It seems to be the points only that can electrify air, even if *they* can. I must make out the cause of the wind at a point; it has a most essential and direct relation to *induction* and also to the (problematical) electrification of air.

3254*. A point was fixed on to a brass conductor insulated and that connected with the Pos. conductor of a machine. When the conductor was charged, if glowing green taper was brought near, the smoke was attracted and then repelled, being driven off principally at the point. When the machine was stopped working, the electricity in the conductor would draw some smoke to it and clothe it and then, if neighbouring objects acting by induction were out of the way and the machine were worked, the smoke did not fly off at random from the conductor, or move hastily, but was gradually directed to the point by the general current of air formed there.

3255. A hand held near the conductor clothed with smoke, when electrified, quickly disturbed it—so also holding the smoking taper near in the hand causes currents, because the hand acts by induction and causes currents.

3256. When a point was held opposite to a conductor charged positively and wax taper smoke evolved near both, the smoke was attracted to the conductor and blown from the point.

3257. When the uncharged conductor was covered with smoke; a point held opposite it, 5 or 6 inches off, and then the conductor electrified, the smoke was blown off from the conductor by the wind from the point. There was no appearance of its going towards

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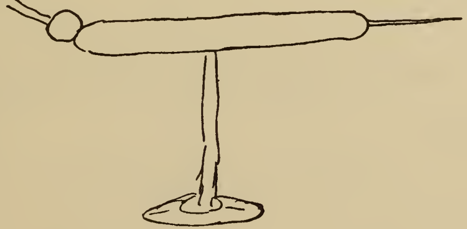
* [3254]



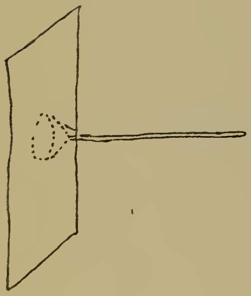
the conductor, or of any motion of the smoke from its becoming electrical. It was simply blown away by the wind from the point.

3258*. A Wollaston's point in glass tube attached to the Pos. conductor gave a sonorous brush. When the machine strongly worked, could bring a quiet glow on to it occasionally. It acted much less effectively as a point than a naked point would have done. When a ball held in the hand was approached towards it, the tendency to form a brush increased. When a point held towards it, then tendency to glow increased. The ball could draw a spark $\frac{3}{4}$ of an inch in length. The approached point could take no spark at all from it.

3259. When the Wollaston point was held opposite the Neg. conductor, it gave at a moderate distance a good brush—or nearer, only a glow, acting as if the point action were in part subdued by sheltering force of the finger or a ball along side of it.

3260†. A very fine Wollaston's point (the end of the glass however being flat) acted in the same manner. It gave very sonorous brushes.

3261. Smoke goes off from charged conductors by these sonorous Wollaston's points and by other sonorous points just in the same manner as from a naked silent glowing point. Hence intermitting discharges do cause a wind.



3262. A point, being a needle, was fixed into a plate of mica by sealing wax, so that the point was level with the flat surface of the mica, there being of course a fine hole through at the place. The Mica was about 3 inches square and when the needle was attached by tin foil to a brass rod connected with a conductor, the point was of course the end of that conductor, but instead of being free in the air, was in the same relation to this mica plane that the point in Wollaston's wire was to the terminal ground plane of glass.

3263. When the conductor was charged, this point gave a glow and discharged, but its action was evidently very greatly diminished, for brushes flew off from the other parts of the conductor in abundance, and I could take good sparks from it. When the hand was approached inductively towards the point, I could very easily obtain brushes from it and even sparks an inch or

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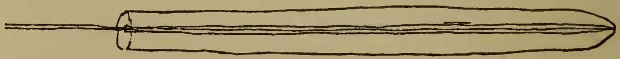
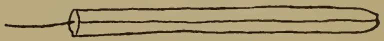
* [3258]

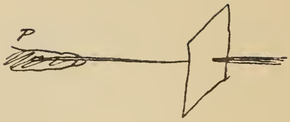


† [3260]

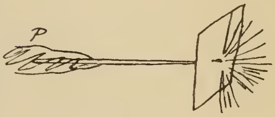


more in length, shewing how much the peculiar action of the point was diminished by this defence of mica.

3264. Still the point had much more of that action than one supposed to be protected in an equal degree by a metal plane.

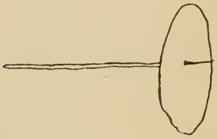


3265. The stream from the point sometimes shot directly outwards, but the brush was of the same character as with a metal ball, i.e. a short straight stem and then a semiglobular set of ramifications. The Stream was accompanied by much wind outwards, the brush not so.



3266. When smoke was accumulated on this conductor with this point on it, the smoke did not move off freely towards the point as before, having indeed but very little tendency that way, but near the mica the streams of air were as shewn in the figure*.

3267. Now had a point penetrating through a disc of mica about 1 inch in diameter. This was attached to the end of the conductor rod and electrified, and when the point projected about $\frac{1}{8}$ of an inch, it acted well, discharging the conductor, producing a star on its extremity and giving neither *brush nor spark*. It produced a strong wind directly out from the point, so that the lateral indraught of air towards the point actually blew off the piece of mica when it fitted only loosely on to the needle, and when fixed tightly on to the needle, it actually pulled needle and all forward out of the temporary tube of tin foil which served to connect it with the brass rod on the conductor (2489).



3268. By smoke brought near it, I found that the currents were as might have been expected and exactly as if an intense, minute jet of air set off from the extreme point of the needle and drew the neighbouring parts into motion.

3269. Is such air bodily electrified P. or N. or is it only electrified with a directed polarity, having gained neither P. nor N. above its natural quantity? This the great question at present; i.e. can an electric be electrified. I do not think a conductor can.

3270†. Now used a piece of mica consisting of a long part (8 inches) for a handle, and at the end a square part about 1 inch in the side, having a round hole about 0·3 of inch in diameter, which could thus be held in different positions to a needle point fixed by a long rod to the conductor of the machine.

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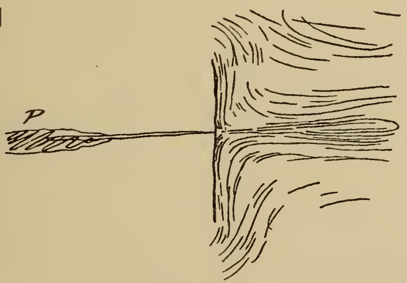
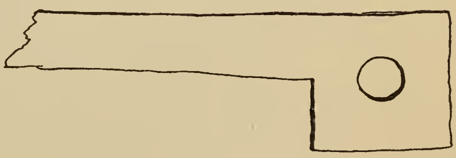
* [3266]



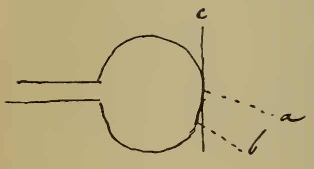
† [3270]



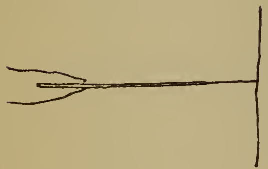
3271*. Whether this screen or piece of mica were held as in the figure or with the point in the plane of the mica, or projecting more or less beyond it, or falling much short of it, still the mica was urged forward with considerable force by the currents of air determined by the point, and that whether the point was directed towards free space or had a large ball brought opposite and towards it.

3272. But the mica became very strongly electrical on both sides, and retained its power strongly; it required to be touched with metal simultaneously on both sides to render it unelectric; the opposite sides being in different states. It was in fact charged.

3273. Took a piece of mica, made a minute hole in it and then put against a ball connected with the conductor of the machine, to see if this hole would at all make part of the metal opposite to it act like a point; but on drawing spark from the place did not find this to be the case. The sparks always abutted on the ball either at the hole, or if that were moved, at the edge of the mica—not penetrating the mica but going over its surface to the hole, but still the sparks were about the same size at the same distance, and were neither more nor less readily formed when the mica was away. Hence the surface opposite the hole had not a higher intensity than elsewhere; was not in fact as a point in any degree.

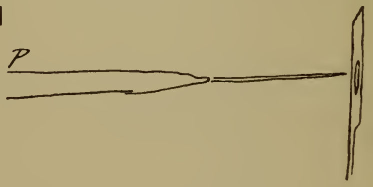


3274. Of course the surface of the mica which was outwards was in the same state as the ball surface would have been, and perhaps at these short distances nearly as strong. Hence the point at *a* opposite the hole in the mica had no more advantage over the point at *b* than it would have had if the plan[e] of mica *c* were away, i.e. as far as regards the induction, and the *induction* determines the discharge and probably the whole superiority of a point over a ball.



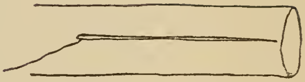
3275. So also, when the point was in the plane of mica, there can easily be induction through the mica, as through the air, so that the point is probably in the same relation as to its state with respect to surrounding bodies as if in free air: but then it is not so with respect to the access of air laterally and behind, and the stream from the point (and the discharge consequently) must be greatly retarded.

* [3271]



3276[*]. Now proceeded to experiment with points in tubes of glass (2488). The first point was a fine steel needle placed in the axis of a glass tube of about the size of the one in the sketch[1], connected with a platina wire which, passing through a hole in the side of the glass tube, could be connected with the conductor of the machine and thus the point be electrified. The glass tube was closed at the further end. The part of the tube from about *a* to the open end had been varnished both inside and outside and well dried.

3277. When the point was level with the plane of the tube mouth or was only a little way inwards and the tube mouth was held towards the Pos. conductor of the machine, it appeared to discharge the conductor nearly as well as a naked needle. Judging by the size of the sparks that could be taken when the points were at certain distances, there was no sensible difference. But when the point was an inch down in the tube[†], then it had lost considerably in its power, and when still further in[‡], it had lost still more power, and required to be brought near a small ball on the conductor[§] before it recovered any thing like its distinct and decided power as a point. When the ball was close up, then it acted nearly as well as if the tube were away, but of course now the relations of the air, its motions, etc. existed in a much smaller space, and probably the space within the tube quite large enough for the purpose.



3278[||]. The same tube with its point, etc. was put onto the Pos. conductor by wrapping a piece of tin foil *b* round the end of the tube, so as to make it and the connecting wire *e* fit into a retort cap *c*, and fitting that cap by tin foil on to the wire *d*, connected

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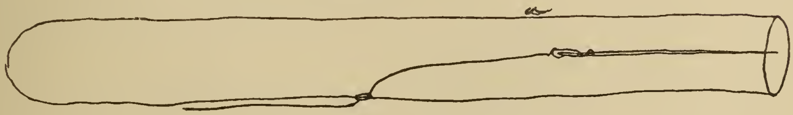
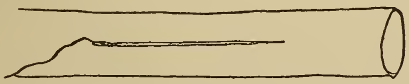
[1] Reduced to $\frac{3}{4}$ scale.

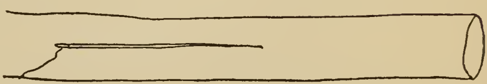
[*] [3276]



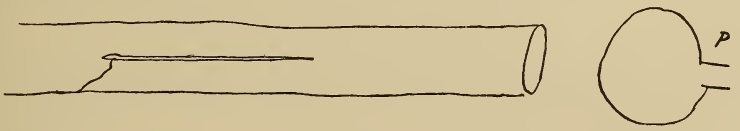
[†] [3277]



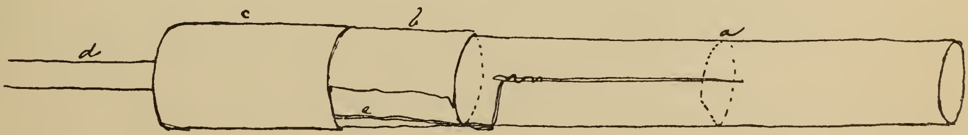
[‡] [3277]



[§] [3277]



[||] [3278]

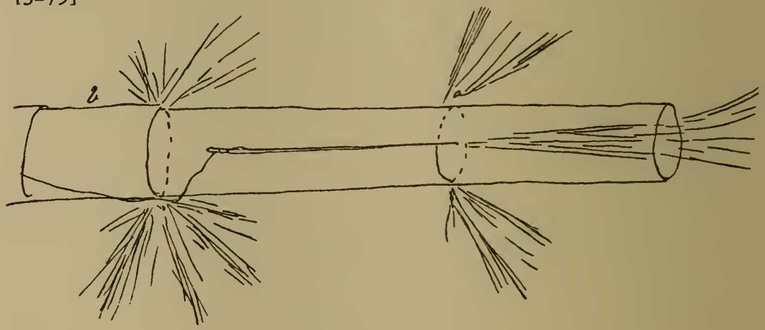


with the conductor of the machine. In this state of things (the point being far in the tube as shewn) it acted as a ball to a ball or the knuckels brought near, the sparks being 3, 4, 5 and even 6 inches long.

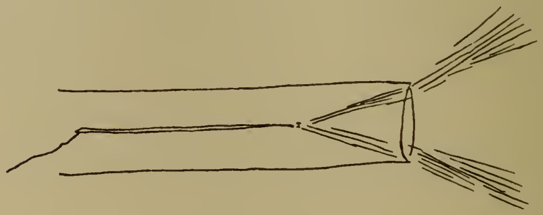
3279*. When no opposed conductor was near, then there were abundant brushes from the edge of the tin foil *b*, also from the place where the varnish terminated at *a*—and from the point through the tube into the air. All these were sonorous and intermitting. That at *a* shewed the great conducting power of the glass in its ordinary state and the much higher insulating power of the varnished surface. Long sparks could be taken from the other parts of the electric conductor.

3280†. Brought the point nearer to the mouth of the tube, making it still Pos. Now there was a constant noisy brush on the point, i.e. there was a star there and brushes from it through the tube to the mouth and into the air, and much smaller sparks only could be obtained from the conductor in other places. The glow at the point appears constant though the issuing brushes intermit. There must also be a current of air inwards near the edges of the tube, for there is a jet of air outwards before the sound of the brush is heard or when the machine is worked slowly, and the smoke of a glowing taper passes in and out again. Whilst there is the wind, there is *no sound* of the brushes, but a glow on the point and even a faint stream right down the middle of the tube‡.

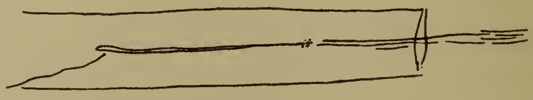
* [3279]



† [3280]

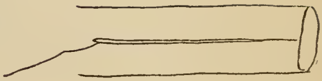


‡ [3280]



3281. When the *Pos.* point was near the mouth of the tube (as thus*) then there was a silent discharge with a star or glow on the point. A spark could be obtained at the conductor, about 0·6 of an inch in length, which was little larger than that which a naked point would allow. When the machine was worked very hard, then a brush could just be obtained on the point in the tube. The effect not far from a naked point.

3282. When the point was a little nearer the mouth but still within, then it was as effective as a naked point.



3283. The approximation of the hand or of *any* inducing surface greatly affects and *facilitates* the discharge from a point—and therefore affects the spark that can be taken from the prime conductor. This happens as much (if not more) with a point in a tube as with an open point.

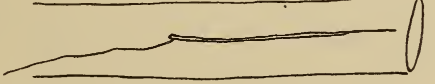
3284†. Now used a tube open at the hinder end, instead of being closed as before, and supported it on the conductor of the E. Machine, so that though the wire was in communication with it, both ends were free. When the point was far in the tube, it gave a spark 4 or 5 inches in length like a small ball, and that nearly in the same degree whether the end *m* was quite open or closed by a cork.

3285. When the end *m* was open, it was found that a considerable current of Air set through the tube when the point was electrified: this was shewn by the direction of the taper smoke, which entered strongly at *m* and was driven out at the other end. Still the taper was at this time held in the hand, and it is just possible this might have produced some of the effect.

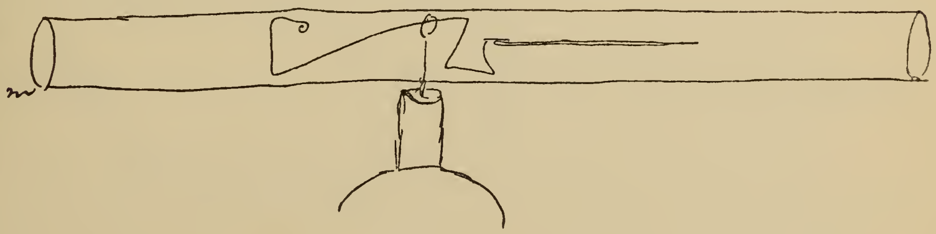
3286. The wax deposited in a solid form from the glowing taper is very inconvenient and is probably also a bad thing in its nature. Must use long filaments of silk suspended from good insulators.

3287. Used a tube three feet long, open at both ends, and with a needle point within, near one end. It gave the same general results as the other, and when the point was about 1 inch within the tube, it produced a strong current through just as in former cases of the shorter tube.

* [3281]



† [3284]



3288*. Employed a narrow glass tube with a point in it. The glass tube had been drawn down from a larger one (as in the sketch) and consequently the narrow part was very thin; it was varnished well outside and inside so as to insulate properly. The point was a fine needle attached to a copper wire passing through a cork at the larger end.

3289. When the needle point was $\frac{1}{8}$ of an inch beyond the narrow end of the glass, the end *a* being in connection with the Pos. conductor, the point acted exactly as an ordinary point. Of course the contracted end of glass tube would scarcely retard or alter the access of air.

3290. When the needle and the aperture were together, it acted almost as well as a naked point.

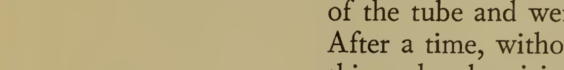
3291. When the point was $\frac{1}{8}$ of an inch within the termination of the fine glass tube, the end of the tube and point gave a chattering brush into the air. Large spark could be taken at the conductor but *not from the point* through the tube—only a chattering brushy spark.

3292†. When further in (about half an inch) and the point opposed to the air, sparks passed from the needle point to the end of the tube and went from thence in brushes or brushy sparks. After a time, without any approximation of ball, hand or other thing, the electricity broke through the glass at the place of the point and then a brush issued from thence and nothing from the end. I could not then obtain a discharge through the inside of the tube to the end. Electricity always went outside at the fracture, often travelling as a spark over the outside to the ball applied at the extremity.

3293‡. Withdrew the point until nearly an inch in from fine end of the tube. For a while streams and sparks passed up to first fracture at *a*, but after a short time it broke through again at *b*, and then no electricity passed from *b* to the end along the inside of the tube.

3294§. Drew the point still further in, when of course it came against a thicker part of the glass. Then worked the machine.

* [3288]



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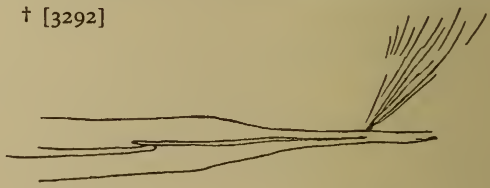
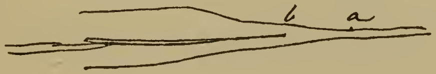
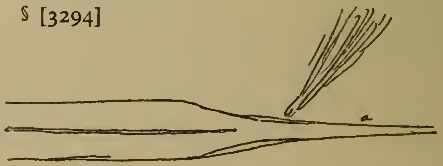


‡ [3293]



§ [3294]



Streams passed up the glass to the hole and from that hole a sonorous brush issued. On working the machine very hard, there was a silent passage within the tube (easily recognised by the absence of the internal sound)—there was a star on the end of the P. point of needle; a bright star at the hole in the glass—and strong sonorous brushes streaming from that hole into the surrounding air. Occasionally there was a feeble glow on the glass between the needle point and the hole at *b*, but generally that space was dark.

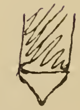
3295. The breaking through the glass is striking effect, for glass, resin, Air and all around were insulators; there was no conductor to give direction by an inductive effect. This probably occasioned by a charge in the glass at the point, the point being Pos., the glass inside Neg., the outside Pos., the Air Neg., and so the charge had risen so high as to cause discharge through by rupture of the glass; but this will go to shew that, as capable of taking up polar or inductive state, glass or resin and air differ, for one must have acted as coating to the other. Again, the same mechanical force which can thus break through glass is probably *that* which, breaking through air so easily about a point, causes the wind, etc.

3296. May, in this way, by charging glass, mica, resin, etc. by point until it breaks through, perhaps get the element of power which by continual recurrence produces the wind. Try this.

3297. It is also striking, that the inside of the varnished glass tube would not conduct, but the outside by preference.

3298*. Proceeded to experiment on the assumption of the conical form by an electrified drop of fluid (2595). Amalgamated the end of a copper wire until it held a good drop of mercury and then electrified it positively. The mercury was very little altered in form, whether exposed to air only or a ball held opposite to it. It became a little more convex downwards and gave brushes or small sparks. Even a glow could be brought over it, but its cohesive attraction too strong to allow great change of form.

3299. A drop of water was hung from the same point and electrified *Pos.* A part was immediately thrown off in small drops; the rest took a shape rather conical and gave off a good sonorous brush. If the hand or a ball were brought near it, the point of water became longer and sharper; but when a *point* was held



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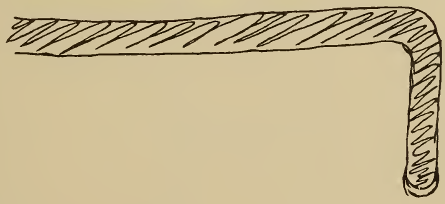
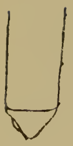
* [3298]



opposite to it, the extremity of the cone retracted itself and the drop became round, there being then *no sound.* If a ball were used so near to the end as to give a spark (about half an inch long), then the sparks were not from the water direct, but their course was from the edge of the metal over the drop of water (which retained its conical form) until it reached the apex, and then darted down to the ball beneath: the passage of many of these sparks over the surface of the water was very beautiful.

3300. When the cone of water is giving a sonorous brush and a point be brought near it, the brush and sound ceases, a glow comes on the water and a light as of a glow star appears at the end of the nipple.



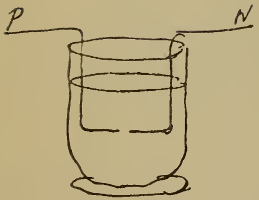
3301. Made the water drop *Neg.* It was now more permanent, i.e. so much water was not driven away, and the cone was more formed, i.e. the sides not concave and the whole not so sharp—apparently as if less air was rushing over its surface, than when it was *Pos.*

3302. A point opposite to it did not cause this negative cone to retract; it kept its form, being the mean while terminated by a brushy star.

3303. When sparks are taken on to this *neg.* cone by either an opposed ball or point, they are I think larger than when the cone is *Pos.*: they go well over the surface of the water.

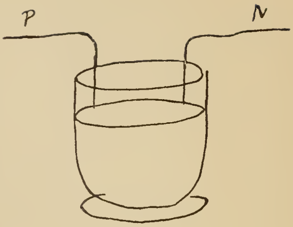
3304. Must again compare the form of Pos. and Neg. drop, using thickened water, as gum water, for the purpose. Also Oil turpentine, Oil, etc. I think it is principally the Air which passes over the surface which gives the conical form and which also carries off the fluid. Compare the effect with currents of air from points on to fluids, etc.

3305. Directed the hanging drop of water downds. towards a surface of water beneath. The drop Neg. When there was a wind from the drop above, there was a depression on the surface of the water beneath. When the two waters were very near and there was a spark from above, then the surface beneath was a little attracted. When the hanging drop was made Pos. the same results followed.



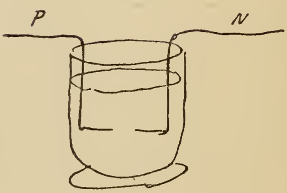
3306. Put two needle points P and N into water very near to each other thus, but there was no effect. The water conducted too well to allow of the points acting. Put minute cuttings of tow into the water to shew the currents.

3307. Opposed the two needle points to different parts of the same surface of water in a jar, not touching the water. There were depressions in the water opposite both points, occasioned by the currents of air setting off from them. The water and air were intermediate conductors between the wires.



3308. Put the N. wire into the water and kept the Pos. point near only. Whilst the point had a star and there was a silent discharge, the water was depressed by the flowing stream of air; but when by bringing the point nearer sonorous brushes passed, then depression of the water ceased. A sonorous passage seems to be independent of current of air. It seems rather as if passage by spark or brush and passage by current of air are two distinct modes. The latter connected with the charge of air, if that be a possible effect.

3309. Now experimented with good *oil of turpentine* into which a few particles of tow had been cut to shew the currents within. At first put both needles in, as in the figure. Immediately there were strong effects and great commotion. The oil of turpentine did *not conduct*, but insulated beautifully.



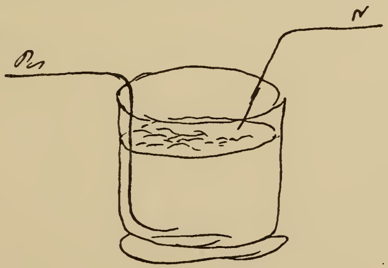
3310. Strong sparks passed between the extreme points of the needles and I doubted whether any silent discharge or current was produced. If there were, the discharge was vastly slower than by points in Air.

3311. The wires *very strongly* attracted each other in the oil of turpentine, far more strongly than in Air. This will relate importantly to charge of electric, induction, repulsion, etc.

3312. The particles of tow flew together, coalescing into a bridge of fibres, evidently conducting from wire to wire very powerfully. They formed a tough band, but when the electricity ceased or one point was taken out, *all* fell to pieces again. This probably a beautiful illustration of the attraction of aggregation and also of chemical affinity.

3313*. On putting the Pos. wire from Machine into the Oil Turpentine, there were violent effects. The whole fluid was in motion and the surface was thrown into strong ripples and undulations by the current of air from the *Neg*. point. The fluid

* [3313]

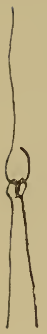


rapidly flowed over to the Pos. wire and a jacket of it rose 3 or 4 inches up that wire to the level of the top of the glass vessel and there formed an envellope $\frac{1}{16}$ of an inch or more in thickness—violently agitated and sending occasionally strong jets of the fluid over the edge of the glass or towards the Neg. wire. At the same time strong brushes darted from these parts of the Pos. wire into the air. The jacket of fluid on this wire could be made to be luminous with *a glow*.

3314. It would seem as if neg. air at point had rendered the particles of oil turpentine *Neg.* and had combined by driving to urge the attracted particles to the Pos. wire, up which they were attracted by virtue of their opposite state, and gradually becoming charged *Pos.* were then driven off in jets, or attract[ed] to the other wire, or assuming sharp forms dispersed the electricity into and across the air.

3315. When the left hand wire was made *Neg.*, still the same results, except that that wire did not give brushes or glow.

3316. When both wires dipped into the oil of turpentine, still great commotion at the surface and beneath, but must take the wires in through glass tubes to avoid surface action.



3317. Made a rough Electrometer of wires—observed these in air—they had a certain apparent repulsion. Put them into Oil of turpentine, when the repulsion appeared vastly greater. The sides of the glass vessel charged strongly from these wires, and on applying the hand on the outside, the glass appeared to take up a charge more strongly than if air had been there. Glass here—Glass in air and Glass in vacuo, compared—Oil of turpentine in this vessel is exactly in the same relation as air is.

3318. Can Oil of turpentine be electrified in a metal vessel, or can a jet of it be electrified. Get a connection here with charge of air, etc. and charge of glass or wax by rubbing them.

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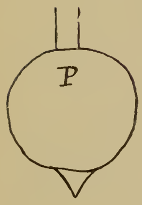
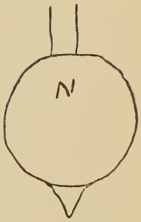


3319. Drops and points of water and other fluids electrified. Water on a ball. When the machine was worked slowly, a fine large cone with concave outline was produced and a steady wind in the direction of the point of the cone. Machine being more quickly worked, brushes were heard—more water was thrown off in minute drops and the smaller pointed portion left was roughish upon the surface, as if exposed to quicker wind passing over its surface. When machine worked very quickly, still more water thrown off by violence of action; what remained elongated and contracted with a rapid alternating motion and a brushy sonorous discharge was heard. The vibrations of the water and the discharge of the successive brushes were probably isochronous.

3320. When this series of effects was produced in the dark, the first large quiet cone had a luminous glow at the end: the sonorous cone had brushes of the common kind.

3321. In these experiments the water was made *Pos.* When a point was held opposite the Pos. drop of water, the latter soon lost its pointed form–it retracted, becoming round, and now the air current was from the Neg. point towards the water–not from the water. This was very evident when the point held a little nearer; the jet of air actually blew the summit of the drop of water into a concave form.

3322. The water drop was now made *Neg.* in free air, no point being opposite to it. A larger water cone than before was produced: it was also much more permanent, and had a short sonorous brush at the summit. Even when the hand was approached, the cone was not destroyed, until an actual small spark passed, and then a little water was thrown off but not much.

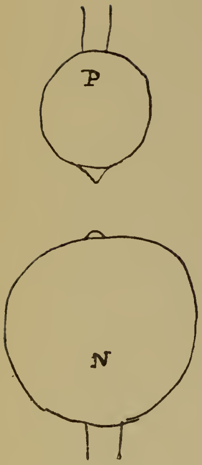


3323. When a point was brought under this negative cone, still the cone was not destroyed and it continued until a spark actually passed. When point a little nearer, the Water point was retracted, and the wind issuing from the Pos. point below rather drove the water away.

3324. In the dark the Neg. cone of water always gave a short brush, even when silent, as when sonorous from the approach of the hand or a ball; but in the latter case the cone *retracted* a little and the brush was larger. When the point or cone changed its form, because of the metallic point beneath, then the brush light disappeared, and the cone was silent.

3325. The elongation and pointed character of the drops is probably due partly to the mechanical action of the current of air over its surface, which itself is due to the form of the drop, and partly to the polarity of the particles of water in the drop, sustained notwithstanding its conducting power by the continual charging at the base and delivering at the sides and apex.

3326. The negative point appears to have a greater tendency to cause wind or brush than the Pos. point. Probably the peculiar character of Pos. and Neg. discharge from conductors into air or electrics in the fluid state may be better examined by fluid points than those of any other material.



3327. Saturated solution of *Muriate of lime* was used instead of *water* for the drop. Whether *Pos.* or *Neg.*, it gave exactly the same results as water, though of course a greatly better conductor.

3328. Put a small drop of the solution of the Mur. lime on a larger ball below held in the hand and took sparks from the one drop to the other. The spark was of the usual bright blue white colour throughout its course, except at the end next the Neg. sol. Mur. lime on the lower ball, and there it was very red.

3329. Made the upper ball *Neg.* and the lower of course *Pos.* Then the spark was again red at one extremity, i.e. at the upper *Neg.* solution. Varied this several times; the spark was always *Red* at the end next the *Neg.* sol. Mur. lime—never at the Positive drop. The spark or discharge was always conducted by the sol. *Mur. of lime*; it never passed over its surface in the manner so common with drops of water.

3330. *Thick Gum water* was used for the drops. When made *Neg.* it gave a very fine large cone: I could not obtain a spark from it; the point became so long and so capable of discharging. (Good form.)

3331. When rendered *Pos.*—More gum water was thrown off than when *Neg.*—the cone became noisy and brushy. Holding a large ball opposite, could obtain a small spark when it was near enough, but were no particular effects as to colour of the spark.

3332. *Syrup* used—Made *Neg.* Was as before—could hardly obtain any sparks—all brush. When sparks did pass, they went over the *surface* of the fluid—there was no particular colour produced. *Syrup* made *Pos.*—more thrown off than when Neg. but still a good cone left—spark at this cone more easy to be obtained than before when *Neg.*—but it went over the surface of the fluid. There was no particular appearance either at P. or N. surface.

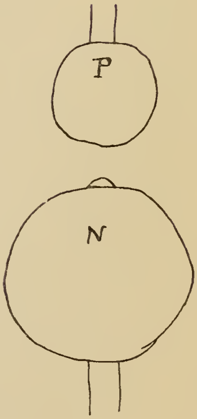
3333. Used *Strong Alcohol* for the cone. Made Pos.—there was a cone but the fluid was very quickly dispersed and disappeared, being driven off in minute drops and by evaporation. When the *Alcohol* was made Neg., the same result was obtained. There was no time to obtain distinct electrical appearances.

3334. *Olive Oil, Neg.*–quickly driven of[f]–is in fact electric like air itself and goes away with the air. When a drop was put on the larger ball below, the spark either pass over it or expand it out. The actions are quite unlike those of water or good conductors.

3335. *Olive oil made Pos.*–the same quick dispersion. When the dispersion was on to a piece of paper held below, the oil spread out, being extended and appearing in quick motion, and radiated in lines from the middle outwards. In fact the air and the brush issuing from the ball above move and spread out the oil, which of course, as it extends over the paper, renders it a worse conductor and the electricity has therefore to seek the edges by the most direct natural rout[e].

3336. *Strong Sol. of Potash.* It gave a good cone, being *Neg.*– and was like water or gum water in the general results of form, brush, etc. etc. When the large ball beneath was approximated considerably, little sparks passed and these were red at the *Neg.* end against the sol. of *Alkali.* The electricity of the sparks was conducted *through* the alkali and not over its surface.

3337. On making the Alkali *Pos.*, more of the fluid was driven off, and the general effects were as with water as to form of brush, etc. When the spark passed, it had a little tendency to red at the *Neg.* surface below. When sparks also from a dry *pos.* ball on to solution of the Alkali–there was only slight reddening effect at the *neg.* end.



3338. Put a drop of *Strong S.A.* on to the lower *Neg.* ball and took sparks from a dry Pos. ball on to it. No redness at the *Neg.* surface was produced.

3339. *Muriate of lime*, tried in the same way, gave good result of red colour at the N. end of spark.

3340. *Sol. Nit. Mercury* tried the same way–no change.

3341. *Sol. Mur. strontia* in the same way gave a fine red termination to the spark.

3342. Sol. *Mur. baryta* in the same way, *not red*, but different to the common spark; was *white* or *greenish* or *grayish white.*

3343. Sol. *Mur. soda*—orange coloured Neg. termination.

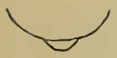
3344. Sol. *Boracic acid* in water—gave no colour. The spark too went over the surface of the drop, not through its substance.

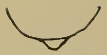
3345. All these effects shew chemical character of the common discharge, inasmuch as they take place at one Pole or surface only. Must try Voltaic discharge in these cases; perhaps of charcoal soaked in dense solution—or mixed powder and water of the salts. Try Boracic acid at Pos. surface.

3346. *Oil of Turpentine*, an insulator as good as air, was now tried as a drop to be electrified. It was instantly carried off just as rapidly as Oil—or Alcohol or Air itself.

3347. *Gum water* was now put on the ball and rendered *Pos.* in a receiver from which the Air could be exhausted, a metal plate being at the bottom of the receiver and the ball so near it (2 inches about) that the action was directly from the ball to the plate and not towards the sides of the jar.

3348. In a very good vacuum there was no sensible change in the shape of the drop when electrified Pos. or if unelectrified. When the pressure within was 10 inches of mercury—the change in shape hardly sensible, E. machine being strongly worked—not at all if weakly worked. At pressure within of 14 or 15 inches of mercury, the form began to be affected, becoming slightly nipple shaped. The discharges were as before this change in form, successive and brushy.





3349. As the density increased within, so the drop became more affected and pointed, and at last a part of the fluid was carried off in fine strings and the same phenomena as those in air ensued.

3350. When the drop within was made Neg. the same course of events followed, except that the drop being larger, it was affected in shape sooner—giving evident change of form when the pressure within was only 9 or 10 inches of mercury.

3351. Now observed the effect produced when a dry ball was made Pos. or Neg. near the surface of water. If near enough, it attracts it and then a discharge takes place. If not near enough to cause a discharge, there was no sensible change of form. If the discharges be reiterated, then the successive attractions and discharges produce a set of stationary undulations.

3352. Have varnished a long glass rod; it is now very dry and does not conduct electricity. On fixing a piece of smoking green taper at the end of it and holding it near a charged conductor, the smoke was much affected. Sometimes a stream to the conductor—sometimes it streamed directly out from the taper away from the conductor, and sometimes it divided, part going to the conductor and another part from the same point from the conductor, moving both ways at once from one spot. But I found the taper a good conductor, and being so irregularly shaped, it acted like a small conducting rod at the end of the insulating glass rod and so produced many currents. When the taper was stuck on the conductor the smoke went off rapidly as from a point, and I could even draw sparks from the end of the taper when the spark of fire put out and no smoke produced.

3353. If smoke be associated with the conductor or be left in the air around, and the taper and rod be removed, then there is no motion in such smoke when the machine is worked—except there be brushes or an offset of air from the end of the conductor.

3354. It appears to me at present that the *glow* is always accompanied by wind or a current of air.

3355. *Points in different situations.*

A piece of mica put up against a point takes away its power as a point and causes it to give sparks to a ball or end brought near—or other parts of the conductor rise so high that they send off brushes, etc. In the dark the light at the point is much reduced but still there is a star or a brushy star there, and electricity appears to be going off from it to the mica and from the mica to the air. If hand or ball brought near, so as to cause a spark, that spark travels over the surface of the mica.

3356. There seems to be a strange aptness for the transfer of electricity either as a spark or insensibly between two surfaces of different matters.

3357*. A needle point at the end of a wire was put into a strong narrow tube which was varnished outside and inside. When the point withdrawn $1\frac{1}{2}$ inches down the tube; still brushes passed from it into the air; the discharge in the tube being *on the surface* of the varnished glass, and on arriving at the mouth of the tube producing brushes into the air.

3358. It gave long ramifying sparks to a ball held near. Could

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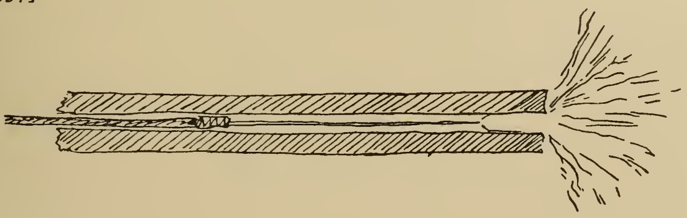
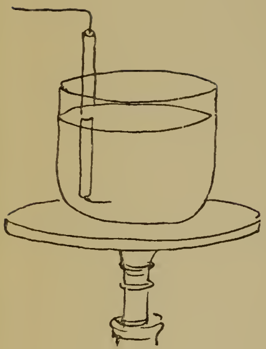
* [3357]



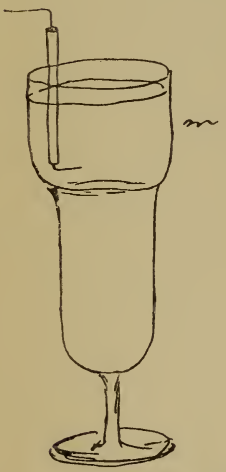
make these go over the surface of the glass, the inside, the edge and the outside; conduction or rather the discharge taking place over the surface in a very striking manner.

3359*. Used a point in the air bent aside from the direction of the rod. The brush from the end of it had considerable flexion from the influence of the neighbouring charged surfaces.

3360. *Oil of turpentine* used as the insulating medium, the wires which were employed as conductors passing occasionally through glass tubes to remove the effect of currents through the air upon the surface of the Oil of Turpentine. Some fine silk particles were used to indicate the motion of the *oil turpentine*; they float very well, and being also nonconductors will do so far.



3361. The Oil of Turpentine was put into a finger basin standing upon a wooden stool, and a wire connected with the *pos.* conductor was introduced through a glass tube, its end being a needle point. The machine was worked and immediately there were violent motions of the whole of the fluid, as if it took up an absolute charge. On removing the charging wire altogether, there were still further appearances of a charge, for a wire held in the air about half an inch from the surface of the oil of turpentine put it into rapid motion—or dipping a wire into the liquid would cause still more rapid motion. On putting a ball and wire into the liquid, thus†, and leaving it there a moment, it was then able to give a spark, as if it had collected electricity from the oil of turpentine.



3362. But found there was no bodily charge of the fluid, and that the whole was an effect of induction through the glass, for on applying hand to the outside of the glass, the ball and wire charged quickly and all the other effects occurred more vigorously.

3363. Took a fresh glass and fresh *Oil of Turpentine*, connected it as before with the machine but also mounted it on an insulating glass. Now there was no movements of the *Oil Turp.* on working the machine; but on applying the hand or a point to the outside of the glass as at *m*, I could then obtain all the motions as before. Hence the effects observed before were due entirely (and easily) to inductive effects and not to any bodily charge of the *Oil Turpentine.*

3364. Now put Oil of Turpentine into a metallic vessel (a platina

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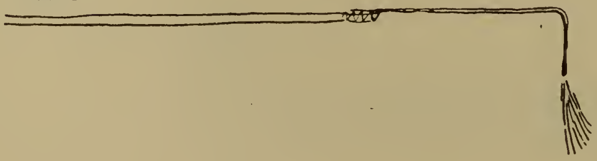
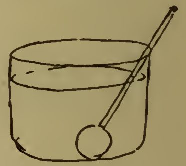
* [3359]



† [3361]



crucible) uninsulated—and caused a wire connected with the machine to descend into it so as not to touch the platina. So long as the machine was worked, there [were] very violent currents in the fluid—exceeding violent—moving all the fluid with extreme rapidity and force. These are the equivalents of the wind in dry air.

3365. But when the Platina vessel was insulated, then there were no currents unless there was at the same time escape from the platina too, and the currents depended as much on the escape of electricity from as on its access to the oil of turpentine.

3366. The currents therefore were not bodily charges of the *Oil Turpentine*, but transferring actions to the platina, which by induction was in an opposite state.

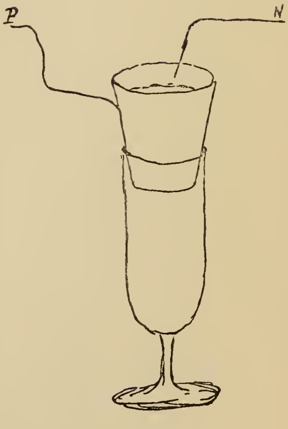
3367. When the crucible with its contents was insulated and connected with the machine and charged, there was no motion in the oil of turpentine except a point or something was brought towards the surface, to which it could act by induction.

3368. The platina crucible with its contents was insulated, charged by contact with the machine, discharged suddenly, and then again examined for the electricity of the O.T.; there was *none there.*

3369. The crucible insulated and its contents charged by a wire dipping into it. This quickly removed, the crucible discharged and after a moment examined again for any electricity of the O.T. None there. This result like that of the tube and Air.

3370. There seems to be *no bodily charge* of the Oil of Turpentine. But when the inductive actions are allowed, the effects are beautiful.

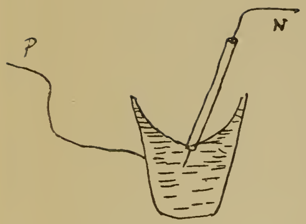
3371. Thus when insulated platina crucible was connected with the Pos. conductor, and a point connected with the discharging train, and therefore Neg. by induction, was held towards the liquid; it caused violent currents and transits and very great commotion in the liquid. Both the Air and the Oil of Turpentine are active in this case as nonconductors. When the knuckle or ball was held towards the surface instead of the point, there was not so much attraction or motion—but it was greater the nearer the knuckle or ball was to the surface.



3372. Oil of Turpentine appears to act as a much stronger inductor than Air.

3373. May carry on these inductive actions causing currents in liquids, to those in solids, where there is no current, through melting rosin, etc. etc.

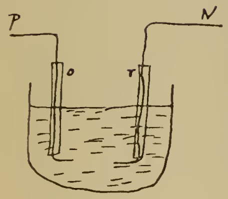
3374. Are surely the same motions as those of Davy's elevations or those of Herschell, etc. of mercury under liquid.



3375*. Now insulated the crucible and its contents, making it positive, but communicated the Neg. wire with the Oil of turpentine through a glass tube, so as to exclude any action of the air at the surface and make the whole a case of contact with the *Oil of Turpentine* only. There was then very violent action and most powerful currents and sometimes even depression in the middle where the wire dipped in to the depth of an inch or more, and when the fluid had been driven below the end of the glass tube, then notwithstanding the discharge produced by the currents, sparks would pass over the surface of the *Oil Turpentine* between the crucible and the wire.

3376. When a brass wire and ball held in the hand was dipped into the *Oil Turp.* instead of the wire end, there were also very violent motions and currents in the liquid. When the ball was brought near the sides of the crucible, quite beneath the fluid, there were bright sparks passed accompanied with sharp sounds. The colour of the spark was yellowish or white. The attraction between the ball and the sides of the crucible was very strong, swaying the ball about in the hand and that with a strong sensible mechanical force.

3377. These attractions connect those of air and those of charged glass, mica, paper, etc. etc.



3378. Now used two points in Oil of turpentine, each being guarded by a glass tube, so that the currents could be observed between them. There were violent currents in the liquid, shewn by the motions of the little particles of silk. The fluid rises a good way up the inside of the tubes *o* and *r*—but these tubes take a strong charge in[1] thin or even if thick, as was shewn by the sparks passing over them. When the points were within half an inch of each other, sparks (strong) passed between them. The currents are not without induction; they are exactly like those in Air.

3379. The silk particles coalesce and gather together wonderfully. If any are present they are sure to be found. They mat

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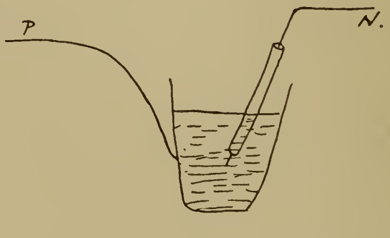
[1] ? if

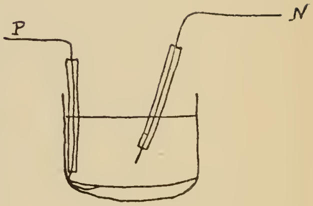
* [3375]



together at, i.e. between, the points and make a very consistent mass, whilst the discharge is passing, but the moment it is stopped, they fall asunder. Looks quite like the attraction of aggregation.

3380. The particles of silk are probably polarized and have probably a real relation to the particles of an electrolyte. I do not think their conduction is the cause of their coming together; but their solidity and their reception of a polar state. They represent the state of the particles of the fluid, and if they were fluid would move as them. Hence they may constitute a step in the indications and experimental evidence.

3381. Now used a silver dish in the oil turpentine as one of the electrodes, a point being the other, and the action of the air being cut off by glass tubes on conducting wires. Here therefore have good induction by using point and plane in opposition. When the dish was made *Pos.* and the *Neg.* discharging wire introduced, the dish was violently moved and carried about by the currents and drawn towards the end of the wire; and during all this time there were violent currents.

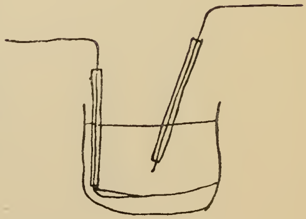


3382. On making the room very dark, I could obtain a *feeble star* on the end of the N. wire. I then made the dish *Neg.* and the point therefore *Pos.* and then procured actual brushes on the Pos. end $\frac{3}{4}$ of an inch long and occasionally little sparks against the *Neg.* dish. The phenomena are exactly of the same nature as those in Air, but more difficult to obtain and also more limited and insignificant, being but feebly luminous; still they were there and with their peculiar P. and N. characters. There were some filaments present in the Oil Turpentine. I must be sure they do not produce the effect. Filter them out.

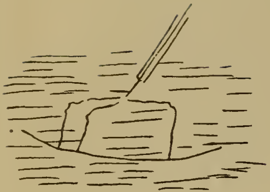
3383. At a certain distance obtained the bright spark in the *Oil Turp.* as usual.

3384. I put a loose ball into the *oil of Turp.* in the platina crucible. It was strongly attracted by the ball in the hand. Shall obtain some good illustrations in this way.

12 JULY 1836.

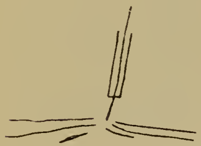


3385. Have filtered the *Oil of Turpentine* and rearranged the apparatus with silver basin below, to obtain star and brush. The point was the point of a needle (perhaps a blunter point would have done better). The needles were fastened to the wires by fine wire, that no fibres should get into the fluid, and all means were taken to insure accuracy.



3386. When silver basin was made *Neg.*, then sparks between it and the point. These were bright, but long by comparison and tortuous, the basin at the same time remaining quiet.

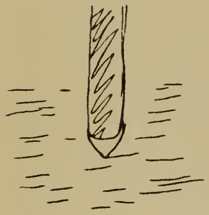
3387. When the basin was made *Pos.*, it was much pulled about in the fluid, as if there more powerful currents or induction from the *N.* point: and the sparks when they occurred were much shorter than before and straight. This consists with the sparks from P. and N. terminations in Air; the P. termination ever readiest to give a spark.



3388. Though difficult to obtain, still I did obtain the brush on the induced P. wire or point, and the star on the induced N. point in the fluid. Both were very feeble. The brush was very divergent and consisting of but few rays. There are some minute fibres in the fluid and I must try again, but I do not doubt the result is a true one.

3389. When sparks are taken from the wire and dish under the surface, minute bubbles of gas rise from different parts of the silver capsule.

3390. Put in a little silk fibre cut; the brushes and star were not better for this. Were also some broken pieces of glass in. Whilst there, obtained brushes, but the star as difficult as before. They probably had no connexion with the fragments of glass.



3391. Now made the Silver capsule Neg. and introduced a *drop of gum water* (thick) at the end of a thick rounded rod, the latter being made *Pos.* On working the machine slowly, the drop was powerfully drawn out into a cone and there were strong currents in the oil of turpentine all round it. It was beautiful to see the drop elongate between the end of the rod and the silver capsule beneath.

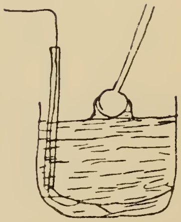
3392. When the end of the rod was clean and dry and a drop of gum water was put on the capsule beneath, then that drop spun out laterally principally. The spinning out of the drop seemed rather to be an effect of attraction than of currents. Still there were very strong currents there and even a *depression* in the drop below when a point held over it in the Oil Turp.

3393. Four or five drops of gum water having been spun off into the Oil of turpentine, which was about a pint in quantity, had rendered it a very good conductor, so that with a strong constant electric action I could now obtain no sparks between wire and spatula, and even the currents themselves have much fallen off. With a spark current at Machine, I could also obtain sparks in the Oil Turpentine, and also brushes and ramifications occasionally, i.e. a sparky brush.

3394. The Oil of turpentine was not quite so clear as before; still it was not importantly misty and I could not tell whether the water was actually dissolved or had only been minutely divided and suspended. It was therefore filtered. It now came out perfectly clear and as good an insulator as ever. Had sparks as long as before and now could obtain *no signs of the brush or star.*

3395. Put a piece of paper into the Oil Turpentine, and used a ball in place of a point as the discharger. The paper flew about in the fluid just as bran or gold leaf in air—being attracted, repelled, etc. on the same principles and in the same manner.

3396. Before the spark has passed there is strong attraction of the ball to the capsule. When the spark has passed, that instantly ceases—no repulsion that I can find at that moment.



3397. When the ball was gradually raised out of the Oil Turpentine, it took up with it a column of the liquid of considerable thickness. If the machine were worked moderately, the column was as the first figured*; when the action was stronger the column was larger and thicker, as in the second figure. There was no doubt both upward and downward currents in these columns, but I must examine them again.

3398. It is evident that the discharge is going on all the time the columns continue. If the ball be taken out and then dipped in again, it will lift up a considerable quantity, with an adhesive appearance as if it were syrup, provided the conductor be not discharged. But if that be discharged, then all is quiet and natural and there is no effect of the kind.

3399. When filings are put into the Oil turp. between the ball

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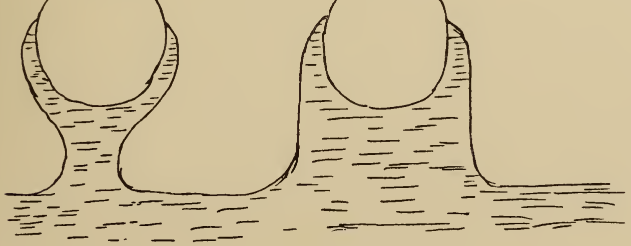
* [3397]

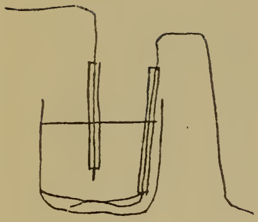


and the capsule, they are both attracted and driven about (by the currents), but there were no striking appearances.

3400. I now removed the silver capsule and put *mercury* in its place at the bottom of the Oil turpentine. When the ball was brought near it, it was attracted up a little and the spark passed.

3401. When the ball (or even point) was further off from the mercury, then violent currents were formed from the ball or point to the mercury—over the surface of the latter to the sides, up which they ascended and then back again. Every now and then, even jets of the *Oil Turpentine* were thrown off into the air.

3402. The *Oil Turpentine* becomes turbid and injured, and can readily obtain light both at P. and N. points in it. But I believe that is because of little conducting particles diffused through it.



3403. Again repeated the experiment for star and brush in clean unexceptionable Oil turpentine, but arranged the apparatus so that the point was made Pos. or Neg. directly from the machine and the silver dish was connected with the discharging train. In this way the point has more power.

3404. When the point was Pos., Brushes were decidedly obtained—the brush was good, though small by comparison with brushes in air. When the point was made *Neg*., then there was the star. The result I believe was very unexceptionable.

28 JULY 1836.

3405. Must shew that bodies do not charge bodily.
„ „ „ all charges are cases of induction or polarity.
„ „ „ excitation of Machine is the same.
„ „ „ when *Pos*. electricity is issuing, *Neg*. electricity is entering. This common knowledge but very important.
„ „ that excitation of machine and the battery is the same.

3406. *Thermo electricity*.

Surely the converse of thermo electricity ought to be obtained experimentally. Pass current through a circuit of anty. and bismuth—or through the compound instrument of Melloni.

3407. In increasing the effect by number of alternations, is it the quantity or the intensity that is increased? If the quantity, that is important to the theory of currents and to the development of the cause. If it is intensity, still the same interest.

3408. The action at the place of contact, if it be at that place, must be most intense, but most minute.

3409. Fuzed chlo. silver with Iron and platina can cause the thermo electric current, and can also conduct it. The conduction is through the fluid and without decomposition.

3410. Will chloride of silver, if partly solid, conduct the thermo current: it does not the voltaic current.

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3411. The charge of a rubbed tube does not appear to be excited by induction (though it may be). How is it excited and how is it rendered polar?

3412. Can there be two ways of obtaining polarity, one by induction, the other by some other condition? Both probably reducible to one general principle.

3413. Is it likely that primary polarization depends upon a relation of the position, etc. of conducting and non-conducting particles?

All would be explained if I could once know the true condition of an electrified conductor, as for instance, the gilt india rubber ball, as it is attracted and repelled by the P. and N. conductor. There must be a difference, when it is positive and when negative; this may be a difference in the state of the electric around it. But how is that state maintained—apparently by the Air of the conductor.

3414. In the case of the *Pos. wind*, there must be a Negative current or transfer in the opposite direction—and Vice Versa. To say *no*, would be to say that a body could be P. or N. alone, or that it could be charged Pos. without losing an equal quantity of *Neg.*, or charged Neg. without losing an equal quantity of Pos.

3415. To say that a body could be charged Pos. or Neg. alone would imply also that there could be a current of Pos. or Negative without the other, i.e. a current of Pos. not having the virtues of a Neg. current in the opposite direction.

3416. In that case too, a current of Pos. one way and a current of Neg. the opposite way would be distinct things and ought to shew different properties.

3417. But as these supposed results are not true results, and there *is* a current of Neg. going one way when a current of Pos. travels in the other direction (or vice versa), then the drops or parts of a stream of air, or oil of turpentine, or wax, etc. etc. must each be polar and not actually Pos. or Negative throughout.

3418. Then these currents are no proof of absolute charge but only of polar arrangement.

3419. All these things bear on the possible charge of a body by other means than those of induction (in which case the charge consists simply of polarity and always respects the insulator, i.e. belongs to it). But as they are true only of polarity, they seem to exclude any other mode of charge and by consequence of excitement.

3420. As a *Main fact*, is it not impossible to obtain one portion of an insulator or electrolyte more positive than Neg., or more Neg. than Pos.? Is not Plus and minus impossible? I believe that it is impossible, any more than that it is possible to obtain a magnet or part of a magnet having more northness than southness.

3421. In electrified conductors, all the electricity is on the surface of the electric, and exists by induction. *Not so.* It exists by induction, but the action commences at the surface of the conductor.

3422. Conductors are probably simply matter in which the state of polarity is quickly discharged, which in fact can hardly assume polarity. Find, if possible, one (a solid) in which power of conduction is intermediate between that of metals and that of Glass or resin. Query Caoutchouc, Wax.

3 AUG. 1836.

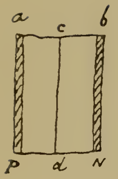
3423. After much consideration (here at Ryde) of the manner in which the electric forces are arranged in the various phenomena generally, I have come to certain conclusions which I will endeavour to note down, without committing myself to any opinion as to the cause of electricity, i.e. as to the nature of the power. If electricity exist independantly of matter, then I think that the hypothesis of one fluid will not stand against that of two fluids. There are, I think, evidently what I may call two elements of power of equal force and acting towards each other. These may conventionally be represented by Oxygen and Hydrogen, which represent them in the voltaic battery. But these powers may be distinguished only *by direction*, and may be no more separate than the North and south forces in the elements of a magnetic needle. They may be the polar points of the forces originally placed in the particles of matter, and the description of the current as an axis of power, which I have formerly given, suggests some similar general expression for the forces of quiescent electricity. *Line of electric tension might do*; and though I shall use the terms Pos. and Neg., by them I merely mean the *termini* of such lines.

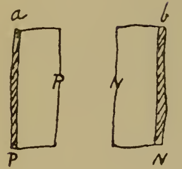
3424. It appears to me at present that we may generalize so far as to compare the various phenomena which take place in conductors together—and also those which take place in non-conductors together. The distinction of the phenomena in conducting and in non-conducting matter appears to be the greatest we can establish, as far as regards the *modes* of action in the various cases. If this difference were explained and reduced to one principle or law, an immense extension of this branch of science would probably result.

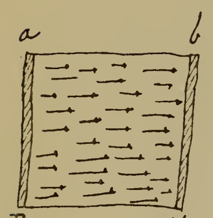
3425. Bodies cannot be charged absolutely as far as my experience goes, only relatively, and by a principle which is the same with that of induction. All *charge* is sustained by induction. All phenomena of *intensity* includes the principle of induction. All *excitation* is dependant as far as I can see on induction. All *currents* involve previous intensity and therefore previous induction.

Induction appears to be the essential principle of the development of electricity.

3426. But both conductors and nonconductors can be charged on their surfaces, provided those surfaces are in contact with an insulator through which induction can take place against another surface equally charged with the opposite electricity.







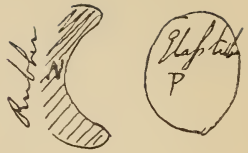
3427. Bodies through which induction takes place are insulators or non conductors. The induction is conveyed through them from particle to particle, and not at once by a single act or impulse from one bounding surface to the other. Thus if *a* be a plate of metal charged P. and exerting all its inductive action through the intervening plate of glass or mica towards *b*, which will be therefore equally *Neg.*; and if the Glass or Mica plate be opened at *c d*, the surface of glass P will be as Pos. as the plate *a*, and the surface of glass N as Neg. as the plate B, i.e. provided the induction of *a* and *b* be still towards each other and through the glass. If the plate glass were opened out anywhere else parallel to *c d*, the same result would be obtained.

3428. Hence every particle between the two inducing surfaces is polarized, or rendered positively and negatively electric on its two opposite sides, in the direction of the line of electric tension; and representing particles thus polarized by a line +—— with a cross mark to represent the positive side, then the particles in the glass are in the position represented, except that the P. part of one particle is no doubt intimately related in force and power to the N. part of the particle next to it at that side.

3429. If the metal plate *a* could be (as it can) removed, then the exposed face of the glass would be Neg. electrified; and if in a similar manner the plate *b* were removed, the face exposed would be Pos. electrified. If both plates could be removed at once, the two sides would be found in opposite states. When however the metal plate is removed, it leaves the substance which replaces it, as the Air itself, in the same state which it had.

3430. This conclusion respecting the relative states of the parts of the particles in the electric or insulator is strengthened by the state of the electrolyte between the electrodes of a Voltaic battery before discharge is allowed and whilst it is in a state of tension.

3431. The following are the conditions of matters under this view.



3432. i. *Excitation.* When Glass tube is excited by amalgam, then the metallic rubber is *Neg.* and the glass left P.

3433*. ii. *Charge of prime conductor by a point.*

This case involves at 4 the discharge by wind or when wind is produced—which will be considered directly—but the metal P becomes electrified the *same* as the glass.

3434†. iii. *Induction* in charge of a *Leyden plate*—and its resolution into charge on metal again.

3435‡. iv. *Discharge by points or wind.*

I think the Air between the P. and N. conductors must be as thus arranged—the wind I suspect to be incidental only—how the discharge takes place I do not as yet perceive. The above arrangement[1] is as unobjectionable as any other requiring polarity in the particles of the insulator—and absolute charge of the particles is disproved by the considerations relating to the current (   ).

3436§. v. *Discharge by conduction.*

This consists in a return from or letting down of that state of the particles of the insulator which constitutes the state of tension, whether the insulator be air, glass, resin or a solid electrolyte

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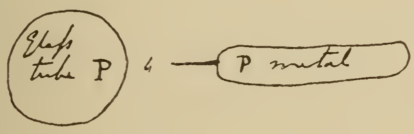
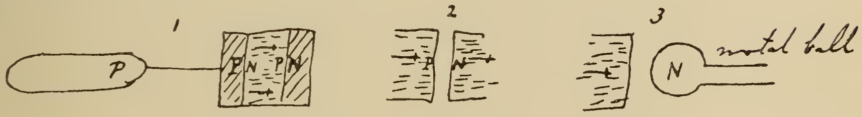
[1] i.e. as in the diagram.

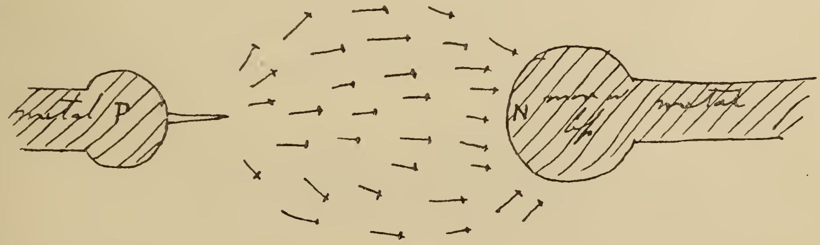
* [3433]



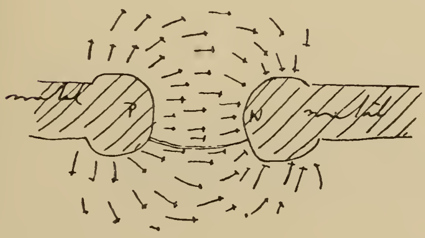
† [3434]



‡ [3435]



§ [3436]



as chloride lead, ice, etc. How the particles of the conductor allow of the transfer of forces is to me a mystery as yet, but it seems to consist in a ready transfer of the force from particle to particle, producing the same result without separation of attracting particles, as is done in an electrolyte by separation of attracting particles. That is done in the compound particle of an electrolyte which here happens in the single particle.

3437. The experiments of Wheatstone shew that the metal is polar for an instant, but that this polarity instantly falls, the sum of free force still remaining at the confines. Now this retardation is probably the result of a very small degree of that force which in insulators is very great and causes their insulating power. They may therefore in reality be like insulators which do not sensibly discharge—or like liquid electrics as Air, Oil turpentine, etc., which discharge by motion, or like Electrolytes which discharge by transfer of chemical power.

3438. There appear to be *three* forms of transfer:

Conduction, as in metals or solid electrolytes, including Air, Oil turp.
Chemical force, as in Voltaic arrangements.
Sparks, brushes, etc.

3439*. vi. *Discharge by Spark.*

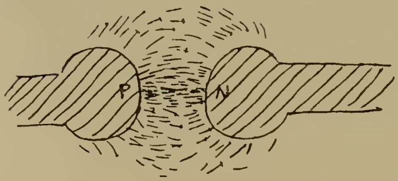
This is a concentration of polarity from a large surface into a small space, and at last destruction of it there, perhaps by a motion of particles. All the neighbouring parts are let down exactly as if a wire had been used to conduct; they therefore *return* back from the state to which they had been raised. Hence the act of transfer by a spark, as by a wire, must be something different to a rise in intensity, though dependant upon that. It is something *equally powerful* but of an exactly *opposite nature.*

3440. This discharge or transfer is probably exactly the same with that of *combustion* and also *local action.*

3441†. vii. *Removal of coatings from a jar.*

The metal U may be taken as the inside coating of a jar and the metal X as the outside. On removing X, the state it had by

* [3439]



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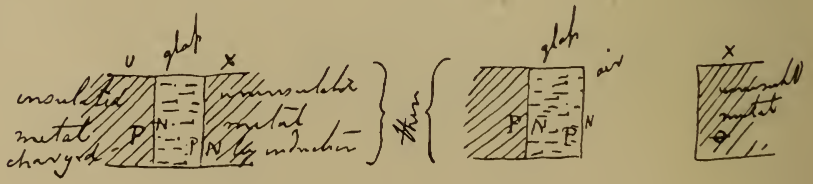

association with the glass and U must be considered as assumed by the Air which replaces it, and it may well be that that Air may assume such a state, for the air against the much smaller surface of the balls of the discharger, when it is used to discharge the jar, suffice to hold the state just before the discharge.

3442. But then this must be a positive and actual charge of that surface of the air, just as it was a real charge of the surface of the metal, which had previously held the same place.

3443*. viii. *Separation of a conductor under induction into two parts.* The course of things are represented by the three diagrams, but the explanation assumes that the metal can now receive a real charge of electricity on its surface, just as before that power had been assumed for the glass. But it seems to me impossible to refuse acceptance to this original or primary charge, though *no accumulation* of one kind or the other alone can be brought out from it. An excited glass tube or rod of wax is a case where the power primarily resides upon the insulator. An excited conductor, insulated or under induction, is a case where it primarily resides upon the metal or conducting body. And a voltaic battery, before its discharge, is a case where it primarily resides upon both electric and conductor.

3444. ix. *Discharge of an excited rod by contact.* The discharge of a primarily excited electric by contact is very important to be understood aright. According to the previous views, it would follow that the conductor as it approaches becomes Neg., taking upon itself the induction which had been generally excited upon surrounding bodies, until it was at last in contact with the rod, and that then its high Neg. state and the rod's high Pos. state were discharged by that kind of action of the particles which

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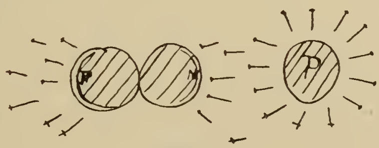
* [3443]



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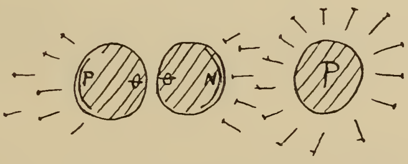

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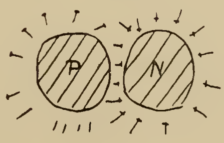


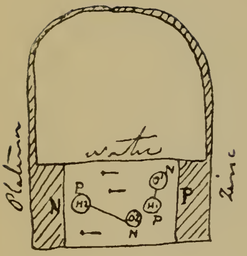
occurs in the discharge between particles of air or water where are no currents, or even in metals.

3445. But that makes the case one which seems to shew that conducting power of metal does not cease at its last particle but at the first particle of the insulator, and that would imply that the electricity of the metallic surface and of the insulator are of the same kind.

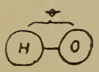
3446*. *Case of Electrolyte and Electric compared.*

If the surface rendered P. by the battery render the surface of the liquid chloride of lead N. by induction, and the phenomena of chemical decomposition seem to shew that, then the surface of the solid chloride of lead in contact with the corresponding surface of platina rendered P. either by the battery or machine, must also be N. and remain so as long as the induction lasts. Now for chloride of lead solid may be substituted Glass, wax, rosin, Oil turp., Air, etc., or any other electric or insulator. Therefore if the surface of an electric under induction is the same as that of the metal against it, then the surface of an electrolyte against an electrode must also be the same in state as the electrode, before the act of letting down or of discharge commences.

3447. *Case of a single pair of plates in a voltaic circuit.*



The exciting cause the affinity of the Zinc and the oxygen of the water; the Zinc is rendered P. and O^1 *Neg.* by that act; O^1 renders its associated H^1 Pos. (in this respect the two resembling a metallic conductor). H^1 being Pos. renders O^2 Neg. by *induction* and O^2 being *Neg.* renders its associated H^2 Pos. by *conduction*, as happened before (by *conduction* or *connection*). The platina is rendered N. both by *connection* with the Pos. Zinc and by induction towards the Pos. H^2, and its power or state of tension towards that particle thus rises to a degree equal to that between the Zinc and O^1. The conduction of the metal is in this respect very important, and acts the same part as the association (whatever that may be) between the O. and H. of the same particle of water. But the origin of the state of tension is between the *P.* Zinc and the *Neg.* Oxygen.



3448. A particle of water is at first and in ordinary circumstances evidently not polar; perhaps it may be represented thus. When a piece of Zinc is put near it (i.e. into water), it is probable it

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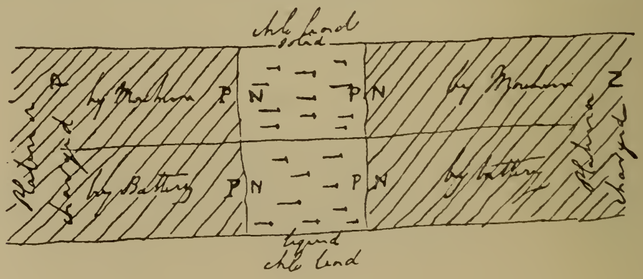
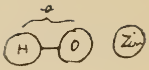
* [3446]

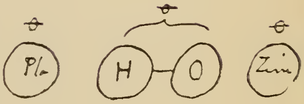


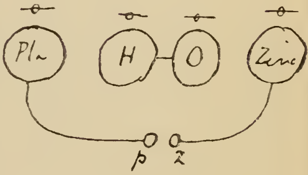
cannot of itself produce any polarity, for induction cannot occur; because the hydrogen cannot become Pos., there being no other surface which can be to it Neg. by induction; the associated oxygen cannot therefore be *Neg.* by the power of the zinc. It is in fact the endeavour (a vain one) to charge a Leyden jar insulated on the outside; or if many particles of water be supposed in association, to charge many jars in succession, the last being unconnected with the ground, so as to complete the circle.

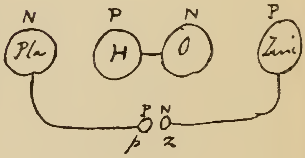


3449. Still there must be a most striking and powerful relation between the Zinc and oxygen in that state—a state of tension which, when accumulated, is the same as that of ordinary excited electricity. But when so accumulated, it exhibits this state of tension when the opposite sides are not connected, though this is perhaps not true, for they are connected by induction, through the Air, the glass or other medium which is employed in the apparatus used to shew the tension.

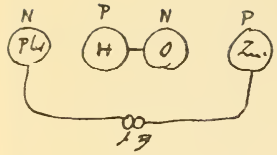
3450. Continuing with the single pair of plates: if a platina piece be brought towards the hydrogen, still all will remain unchanged, because the platina, though tending to become N. through the mutual influence of the Zinc and oxygen, cannot find a part to become, by induction or otherwise, equal *Pos.*, as is essential. But if the platina and Zinc be elongated, so that they may come near each other in some part, and being both conductors, then as the ends *z* and *p* come near each other, they by virtue of the state which the effort at the Zinc and oxygen make, and the fitness of their states to induce towards each other, will assume by induction through the air the electric condition, which will also extend round the circle, and things will acquire this state; the two ends of the Platina and also the two ends of the Zinc not being in the same state but in *opposite* states by conduction, and in that respect each piece of metal resembling the *compound particle* of water.



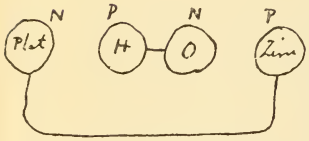


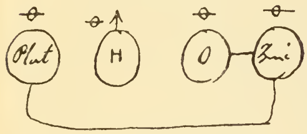


3451. Now when *p* and *z* are so near as to be at the highest state of excitation, just prior to contact, and as high as the action of the zinc and oxygen can make them, *then discharge or rather transfer occurs upon their contact.* It seems to me that this transfer between *p* and *z* does not alter the state of things elsewhere in the circuit, because the Zinc and the Platina will not be more



highly P. and N. after than before; I mean the Zinc and platina in relation to the O. and H.; for take it thus: let the platina and the zinc be before hand in contact, but the platina away from the particle of water*: things will then be as they were when zinc only was approximated to (or rather in contact with) the oxygen (p. 759[1]). Then bringing round the platina until opposite the hydrogen, as it approaches the latter, the induction will occur and the states of the Zinc, Oxygen, hydrogen and Platina will be as before. In this case a current will gradually have passed at *p*, *z* and elsewhere in the metals; before, no current at *p*, *z* occurred, but only induction, which produced the same results at the larger Platina and Zinc. The discharge at last was therefore only a local effect and replaced the induction at *p*, *z*, and discharge is always only a local effect.





3452. This may probably be traced through the luminous tube down to particles of matter and therefore to a simple spark. The discharge or spark was evidently the same thing in a moment across insulators as the current produced in the last case.

3453. Well then, when the power has attained this state, and all the particles are in highly excited conditions, the oxygen leaves the hydrogen to unite to the Zinc, the Hydrogen leaves the oxygen to touch the platina, and then the four particles are in neutral states.

3454. Now as the oxygen and the Zinc in combining have had their mutual inductive actions discharged, a transfer or its equivalent must have occurred between them, and as this is local and solely occupied in discharging the intensity, this act does not produce any result outside these two particles, or in the wire beneath. In the same way, the action between the Plat. and Hydrogen has been entirely local; a transfer has occurred which has discharged their mutual state of induction, but done nothing more, and this has left the particles in a state of freedom. A separation of the particles of the water, or the oxygen and hydrogen, must have had of course an exactly contrary effect in a contrary direction, for it has compensated for the current of electricity which occurred between the two particles, whilst yet combined, without a necessity for a return in the same direction.

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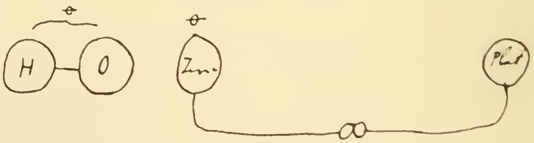
[1] See par. 3448.

* [3451]



3455. Now from these views, if correct, one or two important consequences flow. *First*, the current in the connecting wire is *not due* to the act of combination of each pair of particles of Zinc and Oxygen, but to the previous act of induction. It is that which lifts the current forward a step: then the resolution of the particle of water compensates for that lift and set[s] all in a -θ- state, upon which a freshly exposed particle of zinc and other water acts, and during induction gives another lift, and thus the current is continued.

3456. The current therefore consists of a series of lifts which are succeeded by and compensated for by a series of successive actions.

3457. The entering of a particle into a state of combination or a state of freedom is equally a matter of indifference because

3458. The act of polarizing a compound particle by induction is in fact a virtual separation of the bonds which unite its elements, by the use of antagonist bonds; as these are strengthened, those are weakened.

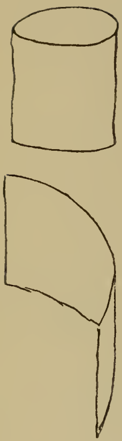
3459. The phenomena give the strongest reason for believing that each particle transfers an equal portion of electricity, and that the electro chemical equivalents represent the weights of the atoms of bodies. This may be a distant, but it is a direct, relation established between the attraction of Gravity and chemical attraction.

3460. Must consider the case of a battery and decompositions, tensions, transfers, etc. etc.

3461. The act of transfer and the letting down the induction of the electrified parts, as in the discharge of a Leyden jar, are two very different things, and the word discharge should not be used for both. The word *discharge* applies very well to the lowering of the charged surfaces, but not to the spark itself, or to the actual transfer, however it may be effected. When the knuckle is opposite the prime conductor, the air is charged by induction; presently a spark passes, and the air is discharged of its polarized state by something which happened in a very small space.

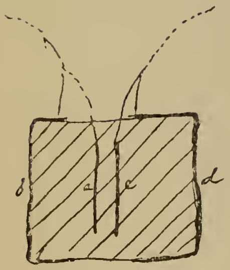
3462. A charged jar will give no electricity to a carrier on its inside, whether the outside be insulated or not. This shews the perfect and complete relation of the two surfaces, which act by induction through the glass. When therefore the ball and cap of a charged jar are away and the outside is uninsulated, the two electricities or Pos. and Neg. forces are then exactly of the same amount.

3463. Hence a conductor charged in a chamber has exactly the same quantity of electricity as the exposed walls of the chamber withinside have of the contrary kind.



3464. If whilst the jar was in that state, both coating[s] were removed, then the surfaces of the Air must be left charged as the coatings were. These forces are solely directed towards each other, because they are of equal amount, and as the air surface withinside must act outwards *only*, so the outer can act inwards only. But suppose it a glass cylinder thus charged, the inside P. and the outside N., by the coatings: then if the coatings were away, all would seem indifferent; but if the cylinder were opened out into a flat sheet, the surface within would then act towards the walls of the room, in part, by induction, and to an equal extent relieving the induction on the opposite side, which would then appear towards the walls and the plate would be Pos. and Neg. on the two sides to external tests; but roll it up into a cylinder again, with either the P. or the N. side inwards, and all signs of electricity on the outside would again disappear.

3465. In this case the surfaces of Air against the glass must have a real charge, as the metal coating surface had, and if the charged glass could be filled and surrounded with glass, then the two electrified planes must be planes of glass really electrified. The great question is, in such cases, how are the boundaries sustained in their electrical state.



3466. Can easily arrange this thus. Suppose a mass of an insulator, glass, resin, etc.; *a* and *b* plates of metal, charged P., and *c* and *d* plates charged *Neg*. Withdraw first *a*, then *b*, and afterwards *c* and *d*, and the whole being closed up hermetically, the part between *a* and *c* must be in an Electrically polar state.

3467. There was an old idea of zones of P. and N. in electrified bodies; must find this out and see what it is. Query Ency. Britannica.

3468. Remarkable points about the Electric current.

3469. In whatever mode an Electric current has passed, there is no loss of power or gain of power.

3470. Neither is there any change or qualification of it.

3471. Its magnetic powers are the same, whether it is passing in an electrolyte, or in a conductor, or in a spark, or in wind or even in inductive action. Such at least seems to be the case.

3472. Again, the strange independance of the power as to matter in some cases strange; thus in my case of rotation of wire and magnet when fixed together, and also in Ampere's case of rotation of magnet on its own axis.

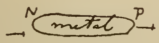
3473. The natural state of the particles of matter and their aptness to assume an electrical state appears to be a primary fact and to come before the common excitation, induction, etc., which would probably flow as consequences from them.

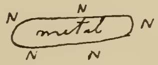
3474. It is a most important fact that elements only are separated as yet as Anions and Cations, i.e., that compounds do not so separate. Considerations arise from this that these are *true elements*, or that Electricity is resoluble into simpler power. See my notes from the Friday Eveng.; but consider cyanogen, etc.

3475. But it would appear probable that Elements can be polarized: thus Sulphur acts as an electric, so I think does dry chlorine, iodine, etc. Hence these can be polarized, but not divided into elements. Hence mobility of the power, or of its direction.

3476. It would seem that any free particle must be supposed to have both states—but that is a question.

3477. When metal or a conductor is used, it is as if the particles of the Electrolyte or non-conductor were in contact in the *direction of the axis of power—not* as if the metal made all the particles of the electrolyte etc. upon its surface have common cause, thus:

Ⓟ makes 

not 

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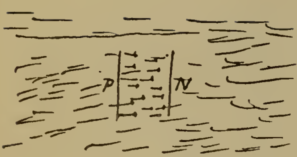
3478. I think that the wind or currents in Air and Oil of turpentine must be an *incidental* and not an *essential* result. If they are essential, then their action would be very important to be understood. Are essential?

3479. Can I get wind from two opposite points at once? I believe not; and that would go far to prove that the wind was not an essential thing and the result of a positive charge, but an incidental result.

3 AUG. 1836.

3480. But then, I cannot do without the discharge of particles, quietly and sans change of place, as in air, oil of turpentine, etc.

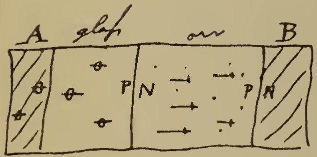


3481. Think this well. If P and N were two surfaces of an electric acting entirely by induction towards each other and having no external relation, then, as a matter of fact, if they could be left free to move, they would be strongly solicited to go towards each other; the polarity of the intermediate matter would disappear, and at last, when P and N should be in contact, their polarity would disappear also and all electricity would be lost. In this case the particles would discharge each other, but without waiting to know how that comes about, will it not account for the currents?

3482. Again—does not this discharge of particle to particle bear upon the way in which electricity tends to travel between the surfaces of conducting matter.

4 AUG. 1836.

3483. When metal surfaces against glass are electrified by induction, and then the metal on one side separated, the removed metal is -θ- and the air between it and the exposed glass surface is -θ-, except the surface of the air which is opposite to or against the glass, and that is as the metal was: thus*



The question may arise, why does not the electric against the metal plate B assume the polarized state, rather than the glass retain it? Why not left thus?

Because the metal surface of A against the glass, and the surface of Air against the glass, are each only half charged (they possess the *sustaining* state), as for instance thus ····+ and —··:·, exerting a positive power only or a negative power only to a distant direction. Unless therefore discharge could take place through the glass particles, or they could be counteracted by opposite forces communicated, they cannot lose these states, and the induction before them must continue, because they sustain and support the action of the intermediate particles.

3484. But then, as B is moved away, there must be a regular transfer of state between it and the air which replaces it and assumes its state; so that the —··:· condition of the former becomes the —··:· condition of the latter, and the -θ- condition of

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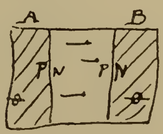
* [3483]



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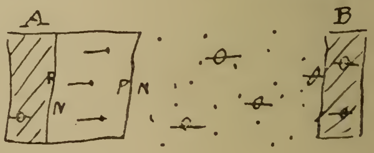
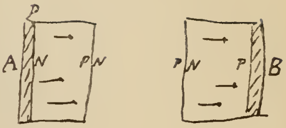


the latter becomes the -o- condition of the former. In that respect the charge of the Air surface and of the metal surface must be exactly equal.

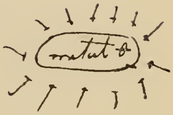
3485. Now this implies conduction from particle to particle between the metal and the air, as above, and between the glass and the air in other circumstances, as perhaps the one figured; and the principle of this giving of power or interchange of conditions exceedingly important. Wish I knew how this takes place; all seems to depend upon it.



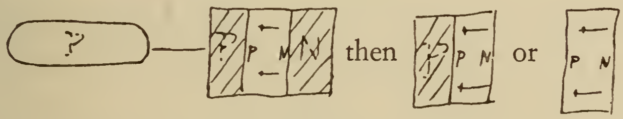
3486. May suppose that conduction does not stop short at the last particle of the conductor, but extends to the first surface of the first particle of the electric. Follow this roughly out.

3487. i. *Excitation*—left as not being supposed to be understood in either case.

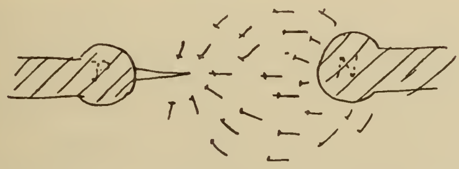
3488. ii. *Charge of a conductor by a point*—left to iv. Conductor thus.



3489. iii. *Induction and its resolution again.*



3490. iv. *Discharge by point or wind.*

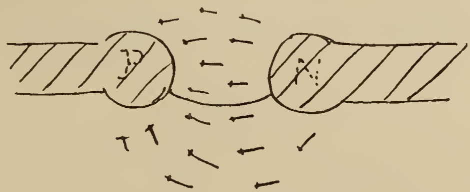


The act of discharge remains, as to neutralization by the moving currents, just as in former case. But particles are supposed to be polarized in the contrary direction.

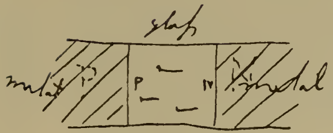
3491*. v. *Discharge by conduction.*

Would consist in a giving up of the state of the particles against the metal to the metal, and its neutralization as before, through the wire.

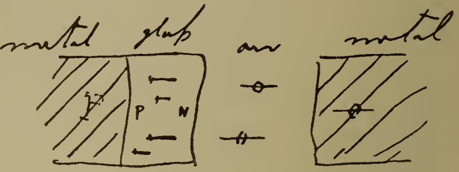
* [3491]



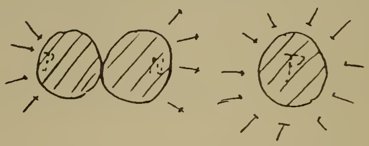
3492. vi. *Discharge by spark.* As before, except that particles are in the reverse direction in the polarized electric.
3493. vii. *Removal of coating from a jar.*



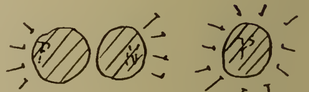
then



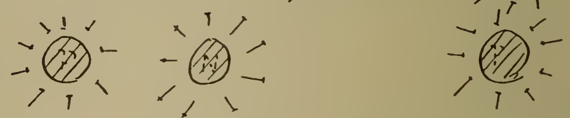
3494. viii. *Separation of a conductor under induction into two parts.*



then becomes



and afterwards



The same difficulty here as before as to the state when in the middle and indeed in all the positions.
3495. ix. *Discharge of excited rod by contact*—simple.
3496*. *Case of Electrolyte and Electric compared.*

This imply, that chlorine was more *apt to become Pos.* than lead and took the Pos. state in preference, and the lead therefore became Neg. in preference, and that the expulsion of the elements or their separation was because the Pos. electrode could make the chlorine a *pos.*, and the *Neg.* electrode render the lead so Neg. in a certain direction as to induce the particles to move on in that direction by successive lifts.
3497. With regard to Voltaic excitation, it does not do much, for the zinc is not supposed to be in an electric state, except by rela-

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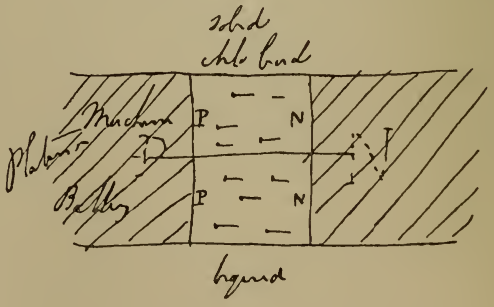
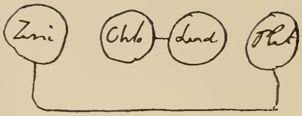
* [3496]

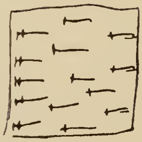


tion to the chlorine, and that relation an inductive one. But it may be considered that the zinc is more intensely positive than the lead, and that, touching the Neg. chlorine, it takes it from the associated lead, and that be advanced to the next chlorine, and so on.



3498. The changes may, as it appears to me at present, be rung upon this principle of communication between the conductor and electrolyte, by true conduction, in all cases, but not so conveniently or simply as in the case of supposing that its last particles act by induction on the Electrolyte and Electric.

3499. The principle of communication appears to require that a plate of Glass electrified by induction should sustain its state of itself; thus * having the metals removed becomes †. But as the power is impressed at the surfaces (or at least at one surface) it seems difficult to resist the impression that that surface must have an overcharge (above mere polarity) unless a power be admitted as residing in the surface opposed to it. That is, if the metal, being inside a jar, be not charged P. on the surface towards the glass, but be –θ–, then the glass must be charged P. so as to sustain the general tendency to return to the indifferent state. Now how can this be done unless it have an extra or positive charge, for it is not related in any way to external particles but only to those which are internal. The whole plate will therefore be rather thus.



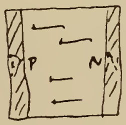
3500. A great difficulty is to decide how particles which can evidently become polar, as those of Electrics, can also become only half polarized, i.e. may be Pos. or Neg. on the side toward surfaces in the opposite state, being then representable thus: +···· or −··:·. If such particles, they seem to have the power of perfectly discharging each other.

3501. Evident that the intensity which is sufficient for decomposition is very low—but the quantity required very great.

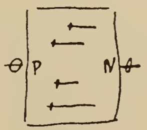
8 AUG. 1836.

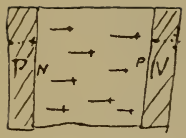
3502. In induction, much as to the relation of the particles within the glass and also the Air or oil of turpentine against it, and respecting Induction generally, may be wrought out.

* [3499]



† [3499]





3503. Let an electric be excited on both sides by induction and then let it be separated into plates, the metal charging plates having been removed*. Then each plate ought to be charged as highly as the original plate, the air between not being polarized or charged at all. And each plate, if lined with conducting plates, ought to give as much electricity as the whole original plate.

3504. If this be true, then the thickness of the plate of the electric will have no influence in resisting the breaking of a discharge through it, provided it be charged always to the same degree, for the power inducing discharge between the metal plate and the N. end of the particle of glass touching it, is the same as that between the Pos. end of that particle and the Neg. end of the next particle, and so on to the end. It is quite likely that it may require more power in a thick plate to polarize all the particles up to the same degree as those in a thin plate, and so thickness may interfere, but probably whenever the power is sufficient to subvert the forces of one set of particles, i.e. those of the metal and the electric touching it, it is sufficient to subvert all the rest.

3505. The greater or smaller facility with which this first element of force is attained may constitute the difference between conductors good and bad, and nonconductors.

3506. In this view of the case, the separated plates ought not to attract each other, except with that degree of force which will be occasioned because of the division of the induction in flat plates between the Glass and the Air. In plates where the induction entirely between the two surfaces, the subdivided plates ought to shew no attraction nor any electricity externally.

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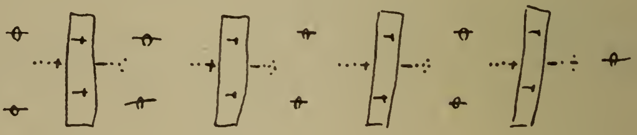
* [3503]



6 SEPT. 1836.

3507. Biot view of Poisson's theory in the article *Electricity* in the Suppt. of Ency. Britannica. He refers to Article *Galvanism*, but there is no such article there.

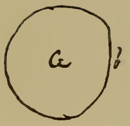
3508. Coulomb proved that all the Electricity in a conductor was external or on the outside—and that the force of attraction was inversely as the square of the distance.

3509. Poisson's theory appears accurately to represent the disposition of the forces when *air* is the Electric considered, but the theory would agree with many other assumptions, as well as that of two fluids, etc. It is very clumsy in its mode of viewing the mutual action of particles of electricity and of air, and the pressure of the electricity against the air, or the pressure of the Air rather against the electricity, as if these two fluid[s] had similar reciprocal actions on each other. It applies only to cases of disposition of electricity, and attractions and repulsions in Air or other constant insulating medium. It does not explain induction or at least not its principle, or else it assumes that the electric force acts in right lines through the inducing electric, as Magnetic forces do through all bodies but iron, and as Gravitating force does. It does not touch voltaic electricity. It is very limited as to its account of the manner in which electricity is associated with the particles of matter or developed in them in the *first instance*. It would probably apply correctly to the idea that Induction is a polarity of particles. It gives no explication (or attempts any) of the nature of conduction—or the difference between that and non-conduction.

3510. Coulomb states that the chemical nature of the conductor has no influence on the disposition or the force of a charge on a conductor. This very striking and important.

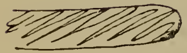
3511. For pressure of air in Poisson's theory, must most probably read charge of air: I think that will meet all the cases. Compare my view of discharge of charged air with Biot expressions in Article Electricity in Supp. to Ency. Britt. at part marked in pencil |3 in the margin.

3512. That induction through Air, etc. does not act in right lines but in lines variously and much curved or bent according to circumstances, is *a strong proof* that it is an action of continuous particles affecting each other in turn, and not an action at a distance. Contrast with direct attraction, as Gravitation or Magnetism, through matters indifferent to it, as Air, Water, Glass, Metal, etc. etc.



3513. If the distribution of Electricity on the parts of a sphere or spheroid can be varied by varying the surrounding insulating medium more or less, then it will shew that this distribution is *not* dependant upon the Air's pressure but upon induction, that being also proved to be dependant upon polarity of particles. Thus, let us make the globe G an electrified conductor and the part *a* sometimes air, sometimes glass, sometimes resin, etc. If the quantity of electricity at *b* on the surface of G varies with these changes, it will shew that the distribution over G's surface does not depend, as in Poisson's theory, on internal condition or upon external pressure of air. It is of course understood that all external inducing conductors shall remain unchanged during the expt.

2 SEPT. 1836 (could not enter these notes before).



3514*. Have had a new apparatus made for discharge in gases, like the former except that sliding wires knobbed outside to prevent accidents. The diameter of the globe was 7 inches and its capacity about cubical inches. The ends of the wire were about this size[1] and both were round and nearly alike; of the two, B end was smaller than A end.

3515. The Globe, being exhausted, was filled with ordinary *coal gas* let into it slowly, through a tube packed with pieces of fuzed chloride of calcium. It remained perfectly clean and bright inside, as if the gas were sufficiently dry.

COAL GAS. 3516. *Common pressure* (29·94 inches in laby.)—A *Pos. from machine—Continuous current.* Sparks occurred in the coal gas until interval between ends was full one inch—they produced a sharp clear sound in the globe—they were sometimes green, sometimes red, and sometimes green in one part and red in another in the

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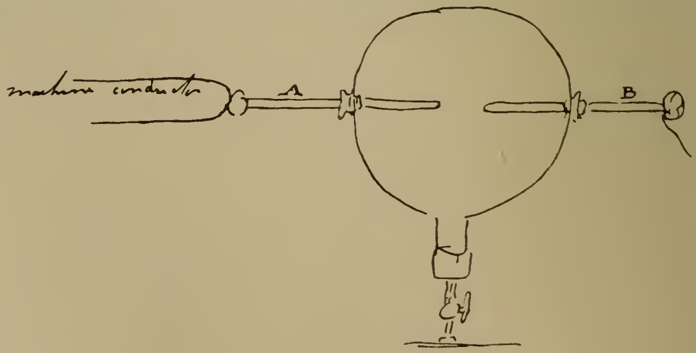
[1] Reduced to $\frac{3}{4}$ scale.

* [3514]



COAL GAS.

same spark; there were also occasionally very sudden black parts, i.e. non-luminous–perhaps the difference of colour, etc. may depend upon the presence of two or more different gases in the coal gas.

3517. At a little greater distance, there were little strong brushes or shoots; they occurred at both ends, were short, had a long dark interval of half an inch or more between the two sets, and often had the quick sharp sound of the spark, as if the discharge through or by this gas was very ready and quick, even when it did not produce a spark or luminous discharge through the whole interval. These brushes were often and indeed generally green.

3518. The sides of the wires ought to be black, or at least if not, it is very needful to be aware of the reflection of the light of the spark, first by the glass inside and then by their surface, which makes the appearance frequently of a glow upon them, when there really is none. This can be distinguished by the place of the apparent glow when the wire is moved.

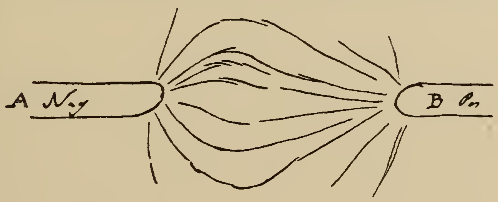
3519. *Common pressure*–A *Neg.–continuous current.* The sparks did not pass through quite such great distance as before, but otherwise the effects were the same.

3520. *Common pressure*–A *Pos.–Spark current.* By small sparks at the conductor, obtained better sparks inside. These were green, red, etc. as before–varying the distance of ends of A and B, did not easily obtain brushes within unless large sparks were taken at the conductor, and then procured them. The brushes were pale in colour and grayish, and appear to come on or occur with difficulty. They are most abundant and best formed on the Pos. end of A, but still are well set on the Neg. end of B.

3521*. *Common pressure*–A *Neg.–Spark current.* Now by large spark at the conductor could obtain the brush discharge across in this form, but it was certainly most brushy at the Pos. end of B, though A connected with the machine. There was a clear difference between the character of the P. and the N. ends, though by no means so great as in Nitrogen, or some other airs. Could obtain the red and green spark light here and there in the course of a discharge, but the brush or ramification always very pale and gray as compared to those in Nitrogen.

3522. A *Pos.–Continuous current–rarefied the coal gas.* When the

* [3521]



COAL GAS. pressure within was about 5 inches of mercury, there was a good discharge of either continuous or spark current. The brushes and ramifications were good as to form but pale and gray in colour. There was nothing else particular.

3523. A *Neg.—Pressure about* 5 *inches of mercury*. Same results as when A Pos., except that with a long spark at the conductor the discharge within was of the straight lambent flame appearance and not in brushes. This straight discharge comes on sooner when A is neg. than when A is Pos.

3524. *Rarefied* until pressure within was only 0·94 of inch, not being able to proceed further at present with the pump. A *Pos.—Continuous current*—the discharge was directly across—resoluble by moving the eye—the light gray and not bright. When the *Spark current* was used, the discharge was flamy and pear shaped and purplish, but nothing like as in nitrogen. On using larger sparks at the conductor, a glow appeared also at each discharge, down the sides of the *Neg. end of* B.

3525. Then made A Neg. The appearances were much the same, except that both the Neg. and Pos. ends were covered with glow when large sparks were taken at the conductor.

CARBONIC ACID GAS. 3526. *Carbonic acid gas*. Made Carbonic acid gas from Whitening and dilute Sulc. acid; received it over water; and passed it slowly into the exhausted globe through the drying tube charged with fuzed chloride of calcium.

3527. *Round ends—Common pressure*, 29·94—A *Pos.—Continuous current*. Sparks passed within, until the ends were full 1½ inches apart—at greater distance the discharge was by a brush having a very feeble light and appearance. The colour of the spark was much like that in Air—perhaps a little brighter and greener—it was fairly sonorous—and had rather an irregular form, not being so near straightness as the spark in air.

3528. A *Neg.—Common pressure—Continuous current*. The sparks passed to a great distance, even to 2 inches; they were bright and beautiful—very irregular in form. At greater distance there was a feeble faint discharge by brushes. At these intervals, much electricity is conducted over the surface of the glass—it would be a good thing if the globe could be varnished.

3529. A *Pos.—Common pressure—Spark current*. With small sparks at conductor, there was discharge by brush at certain distances of ends inside—with larger spark at the conductor there was spark inside, even with wider interval than the last. There is a readiness in this gas to pass the discharge as a spark—and when brushes occur, they are often as good nearly at the *Neg.* as at the *Pos.* end. But must remember that the glass of the globe charges and may interfere with the result.

CARBONIC ACID GAS.

3530. A *Neg.—common pressure—Spark current.* With small sparks, a brush or brush discharge across at small distances inside, but with larger distance inside, spark there with same discharge at conductor as before. The same with large spark current—then had good long sparks inside. The Pos. brush is a little the best generally, but not much, and the brush always poor in character in Carbonic acid at common pressure, either as to colour, light or size.

3531. A *Pos.—Continuous current—Exhaust or rarefy.* As the rarefaction proceeded, the spark within became greenish and it[s] light rapidly diminished. At pressure within of 9·95 inches of mercury, there was a spark of that kind at distances less than 1½ inch. At greater intervals the discharge was by brushes with ramifications but poor as to light or colour.

3532. A *Pos.—Pressure* 9·95 *inches mercury within—Spark current.* With small sparks—stream from A to B when distance small and brush when larger distance. With large sparks—stream between A and B, or when these wider apart pretty good ramifications, and those at the Pos. end better than those at the Neg. end. Did not obtain spark inside with Spark current at conductor.

3533. A *Neg.—Pressure* 9·95 *inches—Continuous current.* At small distances of ends a pale spark as before with continuous current—at larger distances a fair brush at the Pos. end of B and a little brush at Neg. end of A. When the ends were very wide apart could obtain the steady glow on the P. end of B, and a small glow or a star on the Neg. end of A. With *Spark current*, the results were nearly as before, i.e. dull ramifications and those on both ends, but the superiority of the P. end in this respect still preserved.

3534. *Made* A *Pos.—used continuous current* and continued to exhaust. As it proceeded and the rarefaction increased, the light

CARBONIC ACID GAS. between A and B varied in form, and at last became a stream across, having the same form, etc. as in air, but the light was never very good, being of a dull purplish appearance.

3535. At utmost rarefaction, Pressure inside about 0·6 of inch of mercury—*Spark current.* The same discharge across and the glow down the Neg. wire—but the light dull.

3536. *Made* A *Neg.—Pressure* 0·6 *inches—continuous current.* At short distance within, glow on Neg. end of A—then the dark space ( ) very short—then stream straight to B. At greater distances this stream expanded, and separating in the middle distance formed two brushes on the N. and P. ends with a dark space between. The Pos. brush the best. All intermitting.

3537. With *a spark current.* The same as before, i.e. glow upon the sides of the Neg. A, and the discharge straight between the ends—the light better perhaps than before.

3538. In order to contrast the appearances in these two gases with that in Air, now let in Air—exhausted and passed the discharge through. Found that the light was as good as formerly in air and very purple—very different from the Carb. acid gas or the coal gas.

3539. Though Carbonic acid gives but a dull light, it is better than some of the former ones.

3540. The highest exhaustion at the pump was 29·4 inches of mercury.

3540½. Belli (1836) on easier dissipation of Neg. Electy. than of the Pos. in air. Bib. Univ. 1836, Septr., 152. Difference very great and coarse if the results be true.

3 SEPR. 1836.

Barometer in Laby. 29·97.
„ at Pump 29·40 with highest rarefaction.

MURIATIC ACID GAS. 3541. Muriatic acid gas made from Mur. Amm. by Sc. Acid into a jar over strong oil of vitriol to dry it perfectly. Succeeded very well indeed. Gas quite good and clear.

3542. As in experimenting with this gas I could not rarefy by the Air pump, I adopted another plan—and also began the observations in the rarest state of the Atmosphere within, and proceeded on to the densest. Having exhausted the globe (which has a

MURIATIC ACID GAS.

capacity of 180 cubic inches) as much as the pump could effect, then 37 c.i. of the dry M.A. Gas at common pressure were let in, so that, of the mixed atmosphere within, about $\frac{1}{11}$th would be air by volume and $\frac{10}{11}$ths would be M.A. Gas. Then exhausted a large flask about twice the size of the Globe, attached it to the Globe, opened the communications; closed them; blew out the flask atmosphere; re-exhausted it; re-attached it, and re-opened the cocks. The atmosphere of M.A. gas rarefied in this way to somewhat less than a pressure within of 1·97 inches of mercury (   ) was then used as the rarest state of it.

3543. A *Pos.—continuous current—rarefaction* 1·97 *inches Mer.* When the distance of the ends within was small a dull contracted discharge took place across. When the distance was larger, the middle became dark and there was either a glow upon the ends or a mere star.

3544. A *Pos.—rarefaction* 1·97 *inches Mery.—Spark current.* With moderate sparks at the conductor, there were sparks within; they were greenish and pale, and continued until the interval was about 1 inch, and then the discharge was in the form of a stream across of a bluish colour, not purple like that in nitrogen or air. When the distance was more considerable, this stream divided into two or three streams, assuming the character of ramifications. With a larger spark at the conductor, had the same general effect, but not such good sparks inside with the moderate or small interval between the ends of A and B.

3545. The light in this gas was pale as compared to that in Nitrogen, and bluish.

3546. In order to know the degree of exhaustion, the globe was attached to the Air pump guage, and being opened, raised the mercury to 28 inches, giving a pressure within of 1·97 inches to the M.A. Gas atmosphere.

3547. Did not make A Neg. for this pressure.

3548. Let in 30 c.i. of fresh M.A. Gas from over the Sc. Acid, bringing the *pressure within to* 6·47 *inches* mercury; *made* A *Pos.—Continuous current.* Sparks occurred inside until the interval of A and B was about an inch, when of a sudden a dark discharge came on, with a low squat brush or glow or mixture of brush and glow on *each end.* Even when brushy, it was very short—was inter-

MURIATIC ACID GAS. mitting or resoluble. There was no sensible ramification here as yet. The colour of the spark was reddish, but not striking.

3549. A *Pos.—pressure within* 6·47 *inches—Spark current.* With a small distance between A and B, obtained reddish sparks inside. With an interval a little larger, sometimes the discharge was a bright reddish spark and sometimes straight across and flamy, like a very exhausted and sudden but not a dense sharp spark. With greater interval and moderate sparks at the conductor, I obtained a brush on A and a glow on B, pretty fair in shape but poor in light. With large sparks at conductor and a large interval between the ends, had sometimes the discharge straight across, but generally a dull spark occurred at the *conductor*, and then there were mere feeble brushes at A and a glow on B.

3550. A *made Neg.—pressure* 6·47 *inches within—constant current.* The effects the same as when A Pos. With spark current, also the same as nearly as may be, relative to the discharge and the characters of the N. and P. ends. The light was bluish and poor and the spark reddish. The brush at Neg. A often as good as it had been at Pos. A—but the brushy tendency of Pos. B could be observed at times. Still nothing like so much here as in Air or Nitrogen.

3551. On trying the pressure by mercurial guage, it raised it to 23·5 inches or 6·47 inches of mercury within.

3552. Now filled the Globe with M. A. Gas from over the Sulc. acid. It remained quite bright and good, and the brass wires were not at all acted upon during the experiment.

3553. A *Pos.—Pressure common*, 29·97 *inches—Continuous current.* At small distance of A and B, the sparks within were bright and white, or nearly so. Sparks continued to pass until the distance was about 1 inch—then suddenly ceased and I could obtain no signs of brush, glow, or any other light at either end inside. Yet found that by putting a ball opposite the outside of B, there was a very important discharge through the globe and through the M. A. Gas. At last could, now and then, render this silent discharge visible as small spurting brushes, but more oftener dark.

3554. A *Pos.—Pressure* 29·97 *inches—Spark current.* The effects were nearly as before, i.e. at small distances within, bright spark inside; then at quarter distances, either a dark discharge, or a

MURIATIC ACID GAS.

very poor brushy discharge—at greater distance, the discharge quiet and dark. During all this time there were fine brushes from the charged parts of the apparatus into the common air, contrasting strikingly with the effects in the M. A. Gas.

3555. There seems to be a remarkable tendency here to discharge without brush. There is great difficulty in forming a brush or ramification. The spark, when it occurred, always was bright throughout. I did not observe any dark part.

3556. A *Neg.—Pressure* 29·97 *inches—Constant current.* The spark occurred within until distance was about 1 inch. Then a glow on both ends and nearly alike. Brush very rarely observed. Spark always complete throughout its course. When the *spark current* was used, then as before, when the sparks within ceased, it was very difficult to obtain the brush. It was rather a glow on both ends; but the glow on the Pos. B could be observed now and then tending to assume a brushy condition*. When the interval was increased, still the result was the same.

3557. The spark was always complete throughout and nearly white.

3558. During the whole of the experiment the gas was quite clear and the Globe perfectly bright and dry.

3559. During these experiments, observed the outside of the globe to conduct much more than I expected—could produce constant brushes by the knuckles opposite to it. Think perhaps it was rather more than when the globe was filled with common air; but the difference, if any, small.

COMMON AIR.

3560. Now cleared out the Mur. acid gas and introduced common air to compare at once its appearances at common pressure with those just observed in Mur. Acid gas.

3561. A *Neg.—Constant current—common pressure.* Sparks within to distance of an inch—then discharge by luminous stream across or by P. brush and N. brushing star, to distance of 3 inches—and then a glow on each as far as they could be separated, being 4 or 5 inches. With Spark current, there were fine brushes inside on Pos. B and sometimes even on Neg. A. Brush, etc. at the greatest obtainable intervals.

3562. *Made* A *Pos.—common pressure—constant current.* Sparks as before. At greater distance, a low brush on Neg. B and nothing

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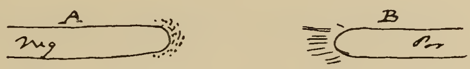
* [3556]



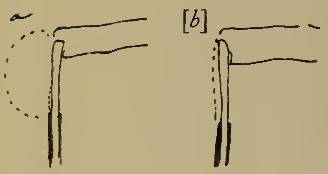
COMMON AIR. on Pos. A, or else a glow sometimes. With the Spark current, there [were] either sparks or else fine large ramifications from Pos. A, as on former occasions with air, and very different to the appearances in M. A. Gas.

3563. Must remember that the highest exhaustion or rarefaction of the M. A. Gas was not equal to that of gases which could be withdrawn directly by the Air pump.

3564. There can be no doubt that the properties of Nitrogen as relates to the phenomena of brushes, discharge, etc. etc. are essential to the production of atmospheric electric phenomena. So the gathering up of the lightning into a brush and then a discharge, etc. Remember that the Air is generally charged Positively, if not always.

12 SEPTR. 1836.

3565. Coating the edge of the lining of a jar with paper is said to retard the discharge—breathing also do something of the same kind. Can this be because the induction through the Air is more round and has a longer course; the partial charge above the edge of the lining having the same effect as rounding the edge of the foil and making it a cylinder would have; i.e. the induction forced to go thus, as at *a*, and not more directly as at *b*.



3566. In my view of induction, discharge through the electric occurs when the particles next to the conductor are so highly polarized as to suffer the phenomenon of discharge, and does not depend upon the tension of the whole series more than is required to bring any one stratum up to that degree. Under that view, a point has the stratum of particles soon brought up to that degree and hence the reason of the discharge there.

3567. The following references are to the Ency. Brit.[1], Vol. vi. Article Electricity.

3568. *Induction.* Good enunciation of principles by Cavallo, p. 444. Cavallo on induction, p. 461. No accumulation, 458, 459. Electricity is on the electric, 460.

3569. *Excitation.* Beccaria on 448. Nicholson on 499, 502, or Phil. Tr., 1789.

3570. *Electricity supposed to be Vibrations*, 452, 461, 465. Light a vibration of the Electric fluid, p. 452.

[1] Third Edition, 1797.

3571. *Glow* noticed and described, 469, 501, 502.

3572. *Gases.* Van Marum on spark, etc. in 505, 507. Colour of the spark. The course or order of colour in Air from perfect vacuum downwards is, according to Morgan, Dark–green–blue–indigo–violet–purple–dark.

3573*. *Conduction*–over surfaces, 452. When a discharge is sent through a long wire of this shape, the discharge will pass at *a* through the air–this clearly shews that the air on the surface of the wire is under induction during the discharge; or that the wire holds a charge for an instant.

3574. If Induction is essential to electrical phenomena of tension, then such phenomena must require *matter*. If also conduction depends upon matter: then the phenomena of a true vacuum ought to differ from both and be peculiar–or else there ought to be both the absence of *induction* and of *conduction* across it.

3575. Morgan's paper on non-conduction is in Phil. Trans., 1785. Davy's in Phil. Trans.

3576. Would be strange if we could prove that no induction across a vacuum.

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3577. The following references are to the first supplement to the Ency. Britannica[1], Vol. i. *Article Electricity.*

3578. *Induction.* Electric meridian, 575–influence of an interposed electric (think power is like gravitation, 577)–polar state of glass and electrics, 600–electricity on the electric, 599–Beccaria, glass plate has innumerable polar strata, 601–Electric capacity, 593, 620.

3579. Charge of air (good), 569–607.

3580. Materiality and transfer, 576.

3581. Excitation; Metal and Glass, 578.

3582. Conducting power, 611.

3583. Points in tube, etc., 607. Brush and stream, 607.

3584. Coulomb's electrometer described, 621.

3585. Epinus' theory, 560. Russel's, De Luc's, 618. Cavendish theory is in the Phil. Trans., lxi.

3586. Must try again the effect of Electric tension on insulators. Try a plate of mica, thin, and stick two prisms on thus so as to

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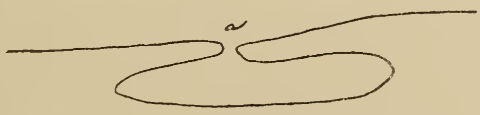
[1] Supplement to Third Edition, 1801.

* [3573]



be able to look through it. Try also thin glass in the same way. See 2512, 2515.

3587. Cavendish theory. Phil. Trans., lxi, p. 584.

3588. *Conduction.* Cavendish does not attempt to explain, p. 649.

3589. Cavendish first shewed that discharge is not by one channel only but, if they are present, by several at the same time. P. T., 1776, p. 197. As discharge is probably preceeded by induction, i.e. polarity of particles, the fact will shew that induction is in curved lines and occurs also in different degrees in different bodies.

3590. *Electric spark*—cause of its light and also of its chemical action on gases—the latter purely mechanical. Biot, Annales de Chimie, liii, p. 321.

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3591. According to Coulomb, all conducting bodies have the same capacity. Now if I can shew that insulators have different capacities, then there would be strong presumption that the electricity in induction is on the electric and not on the conductor.

3592. Electricity feels out its way in advance before a discharge. Harris on Ship's conductors, Nautical Mag. xxvi (No.)[1].

3593. Conduction according to Harris a negative quality. See on ship's conductors, Nautical Almanac, No. xxviii[1]. Now supposing that induction was polarity, and that conductors were bodies incapable of polarity, it would agree with this conclusion of Harris's.

3594. A fine wire in Vacuo will conduct a dischge. over its surface, which would destroy it entirely if in air at common pressure. Query the relation of this to the charge of the air on the surface, or to the diminution of the quantity which actually goes through the wire.

3595. References to *Coulomb's* admirable papers in the Memoires de l'Académie, etc. from 1785.

Torsion balance construction, 1785, pp. 570, 575, 577; 1787, p. 422.
Law of Electric repulsion and attn. 1785, pp. 573, 578, 580, 611.
Points, 1785, 622; 1788, p. 651, 654, 663, 690.
Law of Magnetic force, 1785, pp. 587, 611.

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[1] These references are both to the *Nautical Magazine*, Nos. 26 and 28, Vol. iii, 1834.

Discharge by air, 1785, 613, 615.

. . . . . . Say that when hot is greater, 625. Doubt this if the water is not allowed to increase at same time. What is the cause of the variation spoken of, p. 626?

With reference to *different gases*, 1785, see p. 626.

Conduction of support, 1785, 632. Does not relate to internal conduction. Has close relation to discharge over surfaces, etc., 628.

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3596. *References to Coulomb in Memoire de l'Académie*, etc.

Absolute charge of air, good to quote 1785, p. 613.

Loss by air not affected by nature of the body electrified, whether insulator or good or bad conductor, 1785, 622. Does not this connect the loss with the inductive condition, instead of a condition of charge?

Chemical nature of the conductor has not the least influence on the quantity or intensity of electricity on its surface, 1786, 67, 69.

The electricity is entirely on the surface, 1786, p. 72; 1787, p. 452.

Influence of form—distribution on the surface, 1787, p. 421; 1788, p. 617.

No difference in inductive force of different media, 1787, p. 452, 453. If Coulomb be right here—then no specific power—no action except in right lines, etc.—a most important point.

Electrical kite theory good—1788, p. 654.

Induction, 1788, p. 670, etc.

Theory of two fluids, 1788, p. 671, 673, good. Mem. de l'Institute, viii[1], 213.

Lightning rods, theory of, good, 1788, p. 690.

Magnetism, 1789, p. 455. Mem. de l'Institute, iii, 176; iv, 565; vi, 399.

,, theory of, 1789, p. 481.

Coulomb, Eloge on, by Delambre. Mem. de l'Institute, viii, 206.

Supposed difference of resistance of P. and N. Elect. in Air. Do. viii, 215.

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[1] This and the following two references to Vol. viii are in error for Vol. vii.

22 NOVR. 1836.

3597. Experimented on inductive power of glass. Made a Singer's electrometer electric—the top terminating with a broad plate—then brought another plate near the upper—sometimes air intervening and sometimes also a plate of crown glass. When the glass was there, the electrometer collapsed more than when away, as if induction *more* facil thrgh. glass than air. But this was found to be due to the conducting power of the glass (though it was warm). For in the first place, when the glass was there, then the approach of the inducing plate made no difference, so that induction was evidently not through the glass—and on the other hand, when the plate of metal was taken away, the mere approach and recession of the glass itself made a difference in the divergence of the leaves, approach diminishing the divergence and recession increasing it. In fact, through the conducting power of the glass, the part opposite the upper plate of the electrometer had assumed the opposite state, and hence acted by induction as a conductor itself would do. I must cover the plate with a coat of shell lac.

3RD DECR. 1836.

3598. Have lately made a Coulomb's Electrometer (torsion) from his own directions, and like the instrument very much. The insulation is very good and with repulsions equivalent to forces expressed by the angles of 30°, 40°, 50° or more will hold the charge for 20′ with little sensible diminution. Even when the repulsions indicate 600° or 700°, the loss of forces is very slow.

3599. I have used for the torsion a fine glass thread, according to Ritchie, and find it excellent. With a torsion of 1000° or more, it returns perfectly; there is of course no set.

3600. The first glass thread I used was not fine enough and the lever and pith ball [vibrated] once in 2½ beats of my watch. I then used a silk worm thread, but that was too delicate and appeared to take a set—for instance, when I carried the Index of torsion round Six times, the lever suspended to the thread went round only twice. Sometimes for a single revolution of the Index the pith ball would not move at all. This was probably due to a very feeble electric state in the ball and the want of perfect regularity in the roundness of the glass jar, so that in one position the pith ball was nearer the side than in another, and then would be attracted. The suspension thread was about 2 feet long.

3601. I then used a second thread of glass, very fine, and it now remains attached as the thread for service. It is so fine that the time of vibration of the suspended needle is 13 beats of my watch (140 beats = one minute).

20 DECR. 1836.

3602. Have for some time past been engaged in preparing plates of shell lac, etc. for experiments on induction. Easily cast square and round plates, and then soldered in little loops of white silk into them at various places at the edges, so as to allow of future suspension by long threads of white silk.

3603. I found it exceedingly difficult to free these plates from all electricity, so that they might be used as interposed media in cases of induction without exerting any influence by their own electric state. Handling made them electric—wiping with a dry cloth made them electric—with metal, etc. the same. Wrapping them up in tin foil or paper for days or weeks did not remove this electricity, so perfectly does this body insulate or non-conduct.

3604. The only process I found to succeed was to wash two cloths well in distilled water, wring them as dry as I could, and then, whilst holding the shell lac in one of the wet cloths, wipe it carefully over in every part with the other, and at last deliver the plate into the air, without touching it with any thing else. It is of course dry immediately. It is then free from electricity, and to prove that no film of conducting or interfering matter has been left by the cloth, a mere touch with the finger in any part will render it electric, and that electric state it will retain for hours together undiminished.

3605. All these conditions of the plate, etc. are exceedingly well shewn and examined by means of the Coulomb's electrometer.

20 DECR. 1836.

3606*. *a*, a plate of brass $4\frac{1}{2}$ inches in diameter, insulated on stem of shell lac and connected by a wire 5 inches long with the brass ball *c* half an inch in diameter—*b*, a similar plate of copper opposite *a*, distant $1\frac{1}{4}$ inches from it, and connected with the ground—therefore uninsulated—*d*, a square plate of tin foil $6\frac{1}{2}$ inches in the side, suspended by white silk so that it could be brought between *a* and *b* or removed at pleasure.

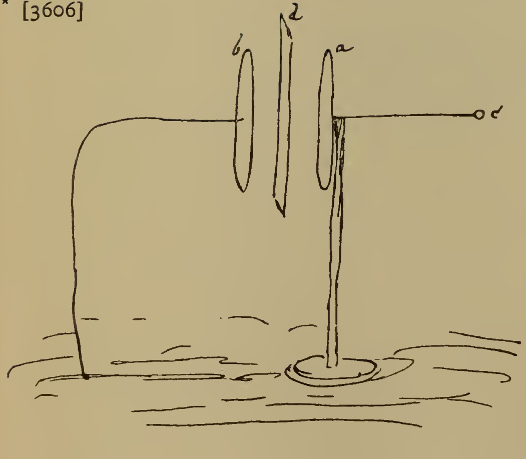
3607. *a*, *c* was then electrified negatively and the ball in Coulomb's balance was also electrified negatively. Then a pith ball at the end of a stem of shell lac was brought to *c*, made to touch it, introduced into the balance and the repulsion observed. Now whether *d* was between *a* and *b* or not, the intensity at *c* was not much affected by it, though *d* was attracted and moved, but not allowed to touch *a*. The effects were less than I expected, but were of no consequence to the general question of specific induction.

21 DECR. 1836.

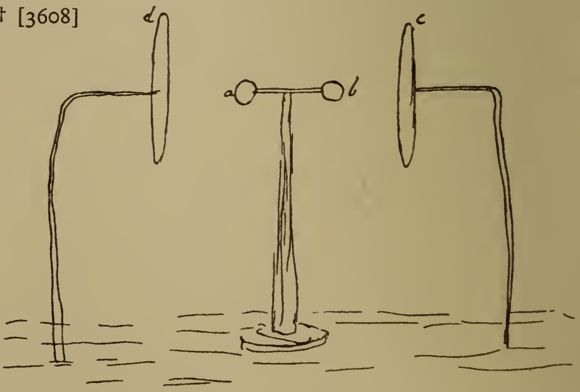
3608†. Experimented carefully in a case of comparitive induction between Air and shell lac. *ab* a small conductor about 4 inches long, consisting of a thick short wire terminated by two similar brass balls $\frac{9}{10}$ of an inch in diameter each. The conductor was insulated on a pillar of solid shell lac—*c* and *d* two metal plates each $4\frac{1}{2}$ inches in diameter, placed in similar positions opposite the two balls *a* and *b*, and connected with the ground; the distance between the balls and the plates was nearly 2 inches. A square plate of shell lac $\frac{7}{10}$ of an inch thick and 5 inches square was then suspended by long white silk threads so that it could hang between *a* and *d* without touching either, or be drawn away to a distance without altering the relative distance of the metallic parts.

3609. Then *a b* was electrified Negatively and of course acted by induction through the air towards *c* and *d*, and in an exactly similar manner. The carrier pith ball of the Coulomb was two or three times brought in contact with *a* and *b*, and with the

* [3606]



† [3608]



repelled or measuring ball in the Balance of torsion, so that the latter was fairly and similarly electrified. After which, observations to be recorded were made thus. The Carrier ball was brought to the extreme end of the conductor at *a* or *b*, then introduced into the Coulomb's balance and the divergence or repulsion of the two balls measured; and this was done successively with the ends *a* and *b*, so as to yield a correct average, sometimes with the plate of shell lac in between *a* and *c* and sometimes away.

3610*. Without shell lac and with air at each end of *a* and *b*, the repulsion was nearly 36° at either extremity.

i 3611. Shell lac introduced between *a* and *d*.

	b	35°
37°·5	*a*	
	b	33°·7
37·0	*a*	
	b	34°·2
36°·4	*a*	

Average of *a*, 36·97 — Average of *b*, 34°·3

ii 3612. Now the shell lac plate removed

	b	34·2
34·2	*a*	
	b	33·8
34	*a*	
	b	34
34	*a*	

Average of *a*, 34°·06 — Average of *b*, 34°

iii 3613. Shell lac between *a* and *d* again

	b	33
34·7	*a*	
	b	32·5
34·7	*a*	
	b	32·5
34·7	*a*	

Average of *a*, 34·7 — Average of *b*, 32·66

iv 3614. I now advanced the metal plate *d* nearer to *a*, indeed close up to the plate of shell lac, which was still in place.

35·3	*a*	
	b	32
35·5	*a*	
	b	31
35	*a*	
	b	31·5

Average of *a*, 35·33 — Average of *b*, 31·5

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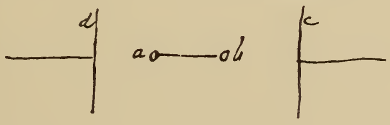
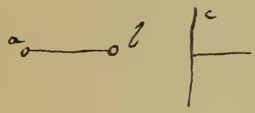
* [3610]



v 3615. Now took away the metal plate *d* altogether, leaving the shell lac plate opposite *a* as it was.

Average of *a*, 32°	33	*a*		
		b	31·5	Average of *b*, 31·5
	32	*a*		
		b	31·5	
	32	*a*		
		b	31·5	



vi 3616. Now took away the shell lac plate also.

Average of *a*, 30·33	31	*a*		
		b	31	Average of *b*, 30·86
	30	*a*		
		b	30·8	
	30	*a*		
		b	30·8	

vii 3617. Brought the plate *c* to within ½ an inch of ball *b*.

Average of *a*, 28	28	*a*		
		b	33·5	Average of *b*, 33·5
	28	*a*		
		b	33·5	
	28	*a*		
		b	33·5	

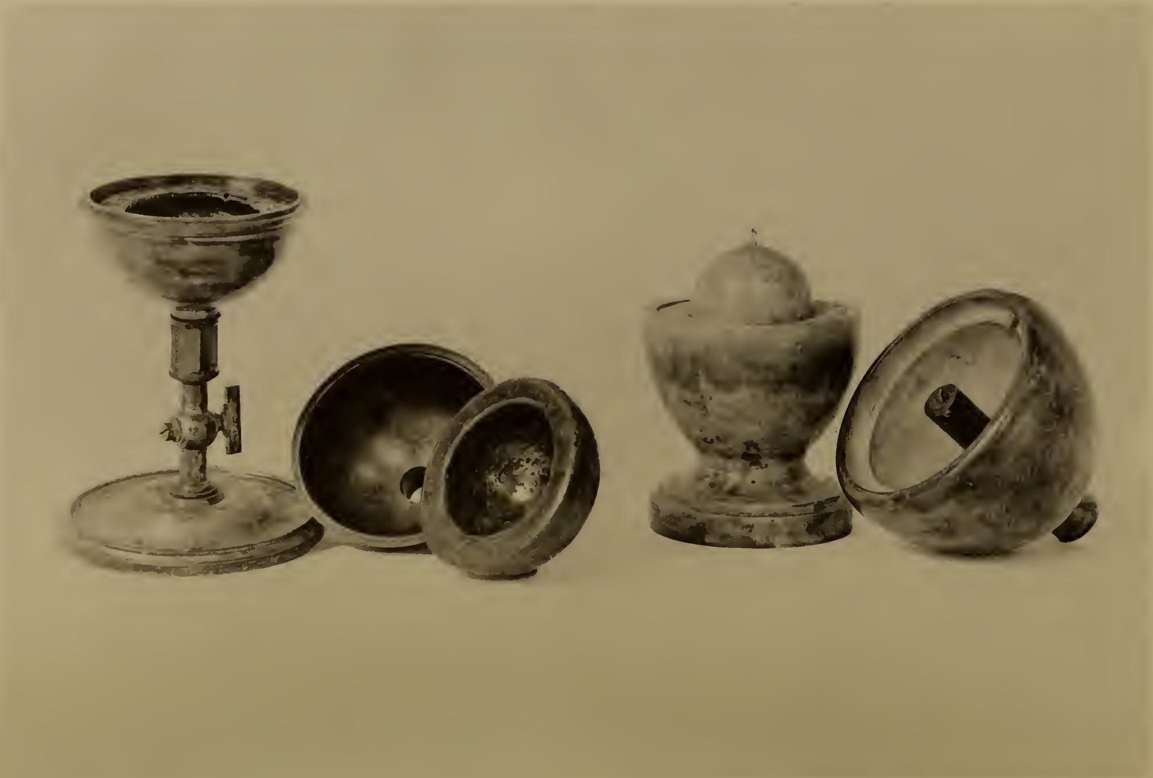
viii 3618. Put the plate of shell lac close up to *a*.

b	32	Average of *b*, 32°
b	32	
b	32	

ix 3619. Took the shell lac away from *a*.

b	32·5	Average of *b*, 32·83
b	33	
b	33	

3620. It is evident from vi that the plates *c*, *d* had not done much by their presence in modifying the general induction at *a* and *b*, as they differ so little in their intensity when one is away. At vii, however, the inductive effect of the plate is evident, and in that state the approach of the shell lac is a little to increase the intensity at the air inductive surface at *b*, as if induction were somewhat more difficult from *a* through shell lac than through air. But this is the reverse of the action in i and iii, which seems to indicate



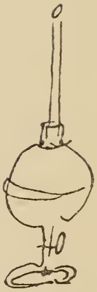
THE SPECIFIC INDUCTIVE CAPACITY APPARATUS

The apparatus of metallic spheres used by Faraday (see par. 3622). The photograph shows the outer sphere in two parts, with examples of the dielectric fillings and the boxwood mould used for preparing them that induction is more facil through *lac* than *air*. The effects however were very small in the difference and probably accidental, and indeed v and vi would seem to shew this, for they indicate no difference whether shell lac or air was next the electrified conducter.

3621. These results seem to shew that induction is alike forcible in both.

23RD DECR. 1836.

3622. Have had two apparatus made for Induction through air and liquids, in which an inner and an outer ball are kept at fixed distances and serve as coatings of Leyden Phials, air being between. They are numbered i and ii and are in all general respects alike. The insulation of the Inner ball is by a metallic wire enclosed in a glass tube, the latter being covered well over with lacquer.



3623. Tried these by charging them alike with Neg. electricity and charging also the indicating ball of Coulomb's electrometer.

	No. i	No. ii
At 9h. 30′ . .	39° divergence	39° divergence.
9 46 . .	25 "	33 "
10 10 . .	18° "	29 "

In these experiments the repelling ball was brought against the upper ball of the two pieces of apparatus and then its repulsion on the indicating ball observed. As the indicating ball would have stood naturally at Zero, the 39° or other quantity not only shews the degrees of torsion overcome but also the *distance* at which that force was overcome.

3624. It is evident from the above experiment, that both i and ii lost electricity rather fast, and No. i most rapidly.

3625. Now rewarmed and revarnished several times over the part of the glass within the great ball, and kept the whole hot for the day to dry the varnish or lacquer *well.* (Pure lacquer was used.) By the close of the day, the glass was well covered with a hard firm coat of shell lac.

3626. Renewed the trial of Yesterday, without previously warming or drying the apparatus.

		Time	i	ii
		10h. 18′	47°	47°
In 0h. 23′	or at	10h. 41′	43°	44°
1h. 5′	„	11h. 23′	39°	41°
1h. 42′	„	12h. 0′	37°	38°
2h. 32′	„	12h. 50′	34°	35°
3h. 40′	„	1h. 58′	30°	31°
4h. 10′	„	2h. 28′	28°·5	29°
4h. 57′	„	3h. 15′	25°	27°
6h. 30′	„	4h. 48′	22°	22°·5
7h. 22′	„	5h. 40′	20°	21°

3627. Here the loss is progressive, and about the same in both, and is also about the same with that of the loss from the balls in the Electrometer. The apparatus will now do.

3628. The Coulomb cannot be trusted except when the balls are nearly equally electrified, or at least not when they are very different. Thus the two balls were both neg. but one weaker than the other: the repulsion was 17°·5; on making them touch so as to equalize their charge, the repulsion was 21°, *with the same electricity*.

29TH DECR. 1836.

3629. Have readjusted the balls and marks of the Coulomb's balance so as to bring all into their places accurately and mark off divergences accurately.

3630. Have also been experimenting with the two ball induction apparatus, but resolved to measure off all the torsion force by the circle above. Therefore adjusted the *repelled* ball so as to stand at 20° in the Electrometer, when the Index above at Zero; then always made the distance from the carrying or *repelling* ball 20° and measured off the force of torsion above.

3631. Charged App. i Negatively; it gave in succession
580
540
488—hence looses rather fast with these high charges. Now divided the charge with App. ii and tried each in succession.

i	ii
255	233
247	230
249	221

These are near enough to shew that the charge is divided and that the sum of the two forces is equivalent to the original force. But seems to indicate, either that ii loses faster than i, or that some cause exists in perhaps both, which lets down the charge for the first moment or two after it is given rather faster than by mere conduction.

3632. Then discharged i entirely, tried ii and found it on two trials

ii
192°
195°

Divided the charge with i and found each as below:

i	ii
106	106
104	105

So that now both nearly equal, but the whole amount of action rather too much, as if a kind of hidden charge had been preserved by App. i. Perhaps it is the taking up of this condition of the electrics, etc. which made the loss before and now makes the advantage. But the general results, that the two apparatus nearly divide the power and give good account of it afterwards is very distinct.

3633. Again,

App. i charged, not so highly:

i
180°
167°
170°—then the charged divided with ii; the indications then were

i	ii
84	78
88	73

To remove the effect of the higher charge of the repelled ball than that of the repelling, brought both into contact; then

i	ii
69°	58°
65°	57°

3634. So evidently the two not fairly charged from each other, for having been in contact outside, they must of necessity present equal influence in the manner they are tried; although it was possible that specific electric induction might have made the mean less than half the original quantity.

3635. Attached App. i to the Air pump. Then electrified ii Neg., tested it and found its force= 170°; connected with i, the air within the latter being rarefied so as to sustain about 12 inches of mercury (Bar. 30·2), then:

i rarefied		ii as usual		
119	. . .	118	sum	237
114	. . .	115	,,	229

This would seem as if rare air had less capacity for Electric induction than dense, but suspect some mistake about first estimate.

3636. Made this expt.

i with common air, charged to . . .	118°	of force
rarefied till pressure within 3·2 in. . .	104	,, ,,
Air let in again, was	104	,, ,,
Rarefied again to 3·5	104	,, ,,

3637. Here the first rarefaction had caused discharge, but after that was attained, dense or rare was the same, and this a good form of experiment.

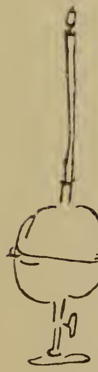
3638. Charged No. i on the Air pump—exhausted it until pressure within was 1 inch mercury—discharge and the force fell to 22°, at distance (always) of 20°. Restored the full pressure of the atmosphere within and the force was still 22°, the same as before.

3639. Hence dense or rare air causes no variation of the inductive force or capability.

3640. Repeated the last experiment. At pressure within app. ii of 1·2 inches mercury, the charge was = to 45° of force of torsion. When Air let in to pressure of 30·2, the force was 43°. This, allowing for discharge by stem, may be considered as identical.

3641. Again no change for change in density of the Air.

3 JANY. 1837.



3642. Experimented with Ox. and Hy. in the two apparatus marked i and ii. Have adjusted so that when Index of torsion was at Zero, the repelled ball stood at 20° of graduation on glass. Then always brought the distance to 20°, and so measured off the whole force of torsion above.

3643. Filled i, *Oxygen*—ii *with Hydrogen.*

Charged i Neg. It then gave, in the torsion electrometer

240	losing fast, apparently by conduction.
214	
203	
190	

Touched ii with it, so as to divide the Electric charge; then

i		ii	
i = 101°	. .	= ii	
	. .	88°	only. Made contact again, then
	. .	88	
91°	. .		
	. .	84	
88	. .		
	. .	74	as ii, so inferior; again made contact
	. .	73	
84	. .		again contact
	. .	81	
78	. .		

It is evident that at the first moment after touching,
3644. i and ii ought to give the same result as to the specimen taken from their outer balls, and the great difference would seem to imply that a part within (perhaps the inside of the tube carrying the wire) takes up the charge slowly, and again gives it slowly as the charge is removed. This would account for the difference between the two after contact provided, as was the case, a little while intervened after contact before the trials were made. For supposing them, at the first moment after contact, to be equal externally to the air round the upper ball: i would have its charge raised a little by the return of the electricity spoken of, and ii would have its charge reduced below the mean by the disposal of a portion of that given to it in the same manner.

3645. Either this or some other circumstance must interfere to cause the difference of intensity in the charge of the two.

3646. It is worth observing that the sum of the two is very nearly the sum of the power originally in i, just before the division. Which seems to shew that Oxygen and Hydrogen are alike in force and amount of Electric induction through them.

3647. Now charged ii containing the Hydrogen Neg. and then divided it with i or Oxygen. Both the oxygen and Hydrogen were dried before they entered the apparatus, and each apparatus was exhausted and filled twice with Gas.

3648. ii, Hydrogen; charged Neg.

188
178 } rapid falling.
168

Then divided with i.

Oxygen, i.	ii, Hydrogen.
	96
90	
	89
85	
	94
79	
	92

3649. Here the sum of power in i and ii being 186 is so much greater than 168, the whole sum when in ii, that it would seem to intimate that Oxygen had less capacity for inductive action than hydrogen, i.e. that half the electricity from ii did not pass into i. But must see how this turns out in other cases.

3650. Again, ii Hydrogen charged Neg.

158
155
147

Then divided with i, Oxygen
. . 78
69 . . touched the two together
. . 74
72 . .

Here the sum of separate forces the same as the first undivided force, as if oxygen and Hydrogen were alike in their inductive capacity.

3651. Experimented to ascertain whether rarefying oxygen would change its capacity.

i, Oxygen was charged N. = 68°
Put on the Air pump and Oxygen remd. until = to 18 inches Mer. = 65°
further rarefaction until atmosphere within support[s] 15 ,, ,, = 67°
,, ,, ,, ,, 6·4 ,, ,, = 62°
,, ,, ,, ,, 2·4 ,, ,, = 66°
,, ,, ,, ,, 1·4 ,, ,, = 58°
,, ,, ,, ,, 1·4 ,, ,, = 58°
then common air let in to full pressure of 30·4 ,, ,, = 60°

3652. Hence no appearance of difference by rarefaction, except that when brought down to 1·4 inches mery., it could not retain the 66° but fell to 58°. The other variations I conclude to be accidental.

3653. Now compared *air* and hydrogen: i, *Air*; ii, *Hydrogen*. ii was charged Neg.

325°
314°
316°

Then divided the charge with i.

. . 215
216 . .

The sum of 429 is so much greater than 316 that I think there must have been a charge left by accident in No. i; or else hydrogen has far greater capacity than air.

3654. Began again, previously discharging both; then charged ii Neg. Was

370°
340°
divided
. . 200
192 . .
. . 210

Here again the same result as before, and very striking, the amount of difference being very great.

3655. Again, ii, Hydrogen charged Neg.

165
158
157
divided
. . 80
79 . .
. . 82
75 . .

Here the half sums are equal to the whole sums, but the first intensity was much lower, and that may make a difference.

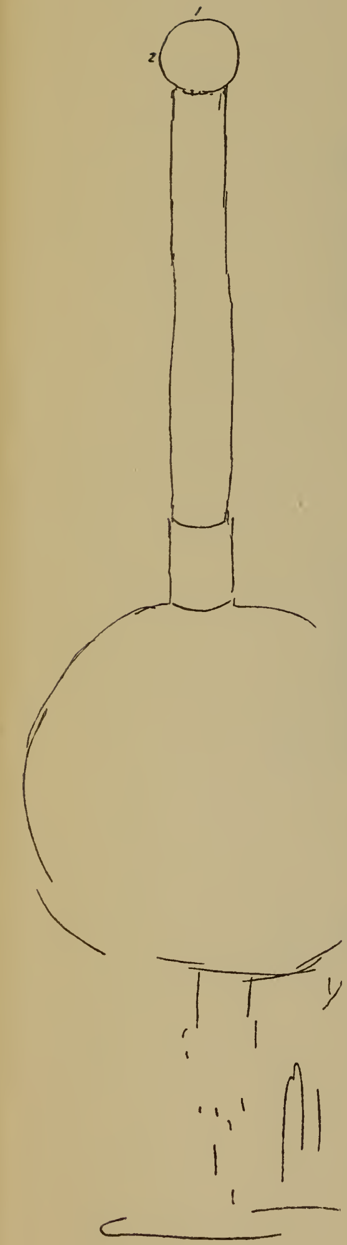
3656. So now took a higher charge for No. ii, in the outset making it Neg.

283 for ii, Hydrogen
250
divided
. . 137
125 . .
. . 135
124 . .

Here the sum is more than it ought to be if powers equal. Also the evidence that when one charged, it takes a portion of electricity, which after a while it gives back again.

3657. Now charged i or air first, ii being hydrogen—

253
247
244
divided
123 . .
. . 115
119 . .
. . 100 made contact of the two, then
. . 104
107 . .



3658. Here the sum is less than the whole, as if really hydrogen had more capacity than air. But I suspect that ii App. has a capability of taking as charge is raised, and giving as charge is reduced, and that this makes a constant difference on its side. Must test this by charging i with hydrogen and ii with Air.

3659. Again, i, Air; ii, Hydrogen, charged i Neg.

265
195
212 } These variations appeared to depend upon slight variations of the position of the carrying ball at the top of the app. i, or passing it nearer to or farther from the edge of the glass covering the Electrometer.
238
227
divided
120 . .
. . 97
105 . .
. . 103
Very irregular.

3660. Now charged i to about 100 and then applied carrying ball to different parts of the ball at the top, and under circumstances of vicinity of other bodies or not:

Applied at 1 with nothing near	101
„ 2, hand being within 7 inches of it	100
„ 1, head and hand over but about 12 inches distance	105
„ 2, body being within 15 inches	100
„ 1, All things being kept clear away	97
„ 1, head, head and hand not far off as before	104

Hence, decided care required as to the position and relation of external bodies, conductors or non-conductors.

3661. Made an expt. on effect of edge of the hole in the glass plate, but did not find much influence there.

3662. Made a last brief experiment.

i Air charged:

97

Divided the charge and instantly took specimen of i and ii:

50 . .

. . 47

This a pretty close result but the original intensity of charge very low.

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3663. Have been removing the glass tube and fixing the balls and rod in their place by shell lac only. Having done one, tried it; at first it was

	160°	of torsion, at interval of 30°.
in 6 minutes it fell to	93°	,,
3 ,, more . .	87°	,,
5 ,, more . .	84°	,,

This a rapid fall from the higher degree and I suspected it arose from *dust inside*, which served as carriers and so discharged the charge. Therefore wiped it well out with

3664. a slightly damp cloth; then very different.

At first it was		. . . .	174	with open angle of 30°.	
After	3 minutes	. . .	172		
,,	23	,, more . .	155	just before Electrometer was	154
,,	21	,, more . .	145	,, ,, ,, ,,	143
,,	23	,, more . .	131	,, ,, ,, ,,	130
,,	29	,, more . .	122		
,,	71	,, ,,	97	,, ,, ,, ,,	82
,,	75	,, ,,	74	,, ,, ,, ,,	60

3665. So that here the charge was well kept—in fact better than in the electrometer itself.

3666. To have a notion experimentally of the forces, a force of torsion of 145 at interval of 30° became a force of torsion of 330° at an interval of 20°, so that the charge had been pretty high.

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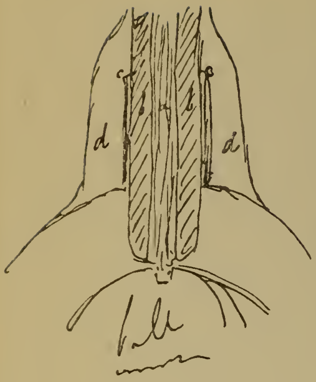
3667. Have now adjusted both apparatus with stems of shell lac; and as the lac does not well adhere to the metal, have been



putting a mass of common cement about the part near the collar of the upper hemisphere to make all tight. *a*, the brass rod and ball, *b*, *b* shell lac; *c*, *c* the brass collar of the upper hemisphere; *d*, *d* the ordinary cement. Here it does not interfere with the insulating or the charging power.

3668. Experimented first as to retaining the charge. The angular distance in the electrometer (constant) was 30°. The time was noted, and also the Electrometer, to compare its holding of charge with the two instruments.

	i.	ii.	
At 1 h. 45'		193°	Electr. as left from the last observation had fallen to
	192°		
		190°	
	187°		
		185°	
1 h. 54' or 9' from first	185°		
2 17 or 32'			165°
		180°	
	178°		
2 37 or 52'			157°
		167°	
	167°		
3 13 or 88'			145°
		158°	
	151°		
3 45 or 120'			134°
		146	
	141		
12 0 or 606'			5°
	30		
		32	

3669. It was evident from these results that the two apparatuses insulated very well, better indeed than the electrometer, probably because the dust had there free access and not in the apparatus. But was also evident that, as both balls of the Electrometer would lose alike, and that the repelled ball was not recharged each time though the repelling ball was; that the apparatus might be considerably charged and yet the effect not be indicated.

3670. On the morng. therefore of the 19th, when the Electrometer was quite down, the apparatus were again examd., but the repelled ball of the electrometer was first brought in contact with the electrified repelling ball (electrified by App. i), so that it might have its charge. The consequence was that:

	i.	ii.
19th at 9^h 30′ A.M. or 1176′ from first	70°	
		84°
	74°	
		84°
8^h 0′ P.M. or 1806 ,, ,,		75°

20th. This morning recharged the repelling ball and from it the repelled ball, and had the following results:

20th.	9^h 15′ A.M. or 2601′ ,, ,,	33°
	2 30 P.M. or 2916′ ,, ,,	27°

3671. Hence the power of holding a charge is quite sufficient for my purpose.

3672. For the purpose of knowing by expt. the value of the force at an interval of 30° for an interval of 20°, I made the observation, and found that 33° of torsion for interval of 30° rose to 80° of torsion for an interval of 20°.

3673. In order to ascertain whether the apparatus would charge and discharge freely and quickly, as well as retain

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a charge, I took the apparatus i, when it exerted a repulsive force of 74° of torsion at an interval of 30°. I then discharged the electrometer balls; next discharged the apparatus i, and could then by the carrying ball find no electricity in it. I waited 10′ and then could find no traces, unless I aided the effect by holding my hand near the top of i as I took the specimen, so as to bring in the force of induction. Then I found very feeble traces—of no consequence. This result very good as it shews that the charge and discharge is quick and complete.

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3674. Again experimented by charging i, then dividing it with ii and testing the sum of the two—discharging ii and again dividing i with it.

i	ii	
210°	0	
205°		made contact of the two and immediately tried the force
103°		
	102°.	The sum of the two is 205° which is very good result. Discharged ii
101°		connected i and ii together
	50°	
51°		

Here again a good result, for the sum is just 101°. Below this, an irregularity crept in, but I forgot to attend to the state of the repelled ball.

3675. Power of dust to discharge appears very great. Have no doubt it was the particles of water in my oil of turpentine, which made it discharge so easily. Perhaps balls of metal attached to masses may collect more dust than balls of non conductors, because they are better carriers off of accidental charges of electricity.

3676. Made a few experiments on the charge when the pressure varied. The app. i was fixed on the air pump, charged and then submitted to variations of pressure and examined without any variation of charge. The interval was always 30°.

Pressure	i.
29·9	88°
29·9	88°
29·9	87°
13·9	87°
29·9	86°
3·4	81°
29·9	81°

3677. 1·9 . . . . . Much discharge of electricity and had therefore to conclude the above observations. From them it appears that Air at 13·9 inches and 29·9 inches pressure are the same to force of induction, and further that the difference of 3·4 and 29·9 caused no difference in the inductive force, except that the rare air could not hold so high a charge as the denser.

3678. Then made interval only 15° for the higher state of rarefaction

1·9 inches 29° at interval of 15°
29·9 ,, 29° ,, ,,

3679. This a very good result. Hence dense and rare air are alike as inductors.

App. i not quite tight.
ii quite tight.

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3680. The apparatus being now tight, proceeded to experiment. The process was to charge one first by contact with a charged metallic conductor—to charge the carrying ball from that, and again the repelled ball from the carrying ball. The carrying ball was then re-charged from the instrument, and its repulsive force on the repelled ball noticed; a second observation was made and noted. If the two agreed nearly, then the uncharged and the charged apparatus were put into contact for a few minutes, and then the carrying ball used to take a specimen first from the one and then the other. It will be perceived from the order and arrangement of the data below, which was first charged. When two gases were compared, first the one was charged and divided, and then the other. The distance at which the forces were measured was always the same, namely 30°.

3681. *Oxygen and Hydrogen.*

OXYGEN AND HYDROGEN.

	i, Oxygen.	ii, Hydrogen.
	292° . .	
	290° . .	
	charge divided	
	. .	145°
	144° . .	
Again		
	. .	225°
	. .	225°
	charge divided	
	. .	114°
	112° . .	

Very good results—shew that Oxygen and Hydrogen are alike in their inductive capacity.

3682. After this, had with high numbers some very irregular results, for the sum of the two divided portions was more than the whole original amount of force, and that whether the Oxygen or the Hydrogen was charged and divided.

OXYGEN AND HYDROGEN.

3683. Found that this was due to some quick charge and discharge of either dust or fibre or something extra when high charges were taken, and on repeating the experiments with lower charges had regular results.

3684. i, Oxygen ii, Hydrogen
346° . .
340° . .
315° . .
} a pretty fair result.
divided
160° . .
= 315°
. . 155°

3685. Again . . . .
. 195°
. . 192°
divided
. . 97°
= 194°
97° . .

Very fair results—and appears so whether the oxygen or the hydrogen be first charged. Had there been a specific capacity, there would have been deficiency one way and excess the other.

3686. Again . .
i, Oxygen ii, Hydrogen
188° . .
185° . .
divided
92° . .
= 184°
. . 92°

3687. Again . . . .
. . 115°
divided
58° . .
= 117
. . 59

OXYGEN AND HYDROGEN.

3688. Again . .

i, Oxygen		ii, Hydrogen
		. . 281°
	left it some time, then	
		. . 228°
	divided	
116° . .		
		= 232°
		. . 116°

3689. There is a little difference, but nothing to disturb the result. Generally, the two divided forces are a little more than the original force, as in this case 4°, and this is more the case when ii was first charged, than when i was first charged. It probably depends upon the two apparatus not being exactly equal in their arrangements.

3690. All the former trials, i.e. those up to this time, were made with Neg. Electricity.

3691. Now took some higher charges, and here was evident the care required in estimating the forces.

i, Oxygen		ii, Hydrogen
568° . .		
555° . .		
545° . .		
	divided	
265° . .		
		= 520° only
		. . 255°

Brought the two apparatus again in contact; then

265° . .		
		= 535°
		. . 270°

and considering what must have been lost during the time occupied, this a very good result.

3692. Again, ...

	. . 545°		Average loss 20°
	. . 525°		
	divided		
	. . 255°		loss 15°
255° . .		= 510	
	. . 250°		loss 9°
251° . .		= 501	

Results good again. Gases must be alike in power.

3693. In all these experiments, the repelled ball had been left unchanged in its state for the measurement of the whole and of the half force, and it was evident that it was in neither case charged to the same degree as the carrying ball. To test the effect of this difference, App. i was taken as charged to 248° after the close of the last expt.; both balls of the electrometer were discharged; then the carrier charged from app. i at 248° and next used to charge the repelled ball in the electrometer. Supposing the two balls had divided the electricity, each might be considered as retaing. the quantity of 124°. The repelled ball was left in this state; but now, App. i had its charge divided with ii, bringing it down to about 124°, and then ii being discharged, it was used to halve the charge of i, so as to reduce it to about 62°.

3694. Now the carrier ball was charged at i, and would have a force of about 62°, but evidently much less than the electricity of the repelled ball left at about 124°—and when the mutual action of the two in the electrometer was observed at the angular distance of 30°, the amount of force of torsion was 65°.

3695. Then by a thread of shell lac the two balls in the electrometer were brought together, so as to divide equally their charges, and then their mutual repulsive force at 30° was observed again and found to rise up to 82°, or about half the sum of the force of the charges of the two balls.

3696. Again, the balls were highly charged, so that the repulsive force between them was 348°. The repelling ball was then taken out, reduced to a feeble charge and the mutual repulsive force was now only 51°. Made the two approximate—at a certain distance there was attraction between them—contact and immediately powerful repulsion, amounting now to 70°.

3697. Hence if there be a difference between the charge of two balls, and that difference be great, it will seriously affect the expression of repulsive force. Theoretically, the two balls being of equal size, they will repel each other with the greatest amount of force when the charge is equally divided between them, and the repulsive force will become less and less as they differ from each other in their portions of the charge, though the amount be the same.

3698. The repelled ball may perhaps best have a medium charge, between the higher and the lower charges which have to be compared. And then provided it remains unchanged (sensibly), it will at 30° distance give indications probably very nearly those of the quantities of electricity in the repelling ball. It is very evident that the repelled ball must not change with the repelling ball, unless indeed both were brought to the same state, and to the state of the apparatus tested, and then (I think) the electricity in the apparatus would be as the square root of the forces of torsion indicated.

3699. The little hole I had made in the inner ball to allow of the air or gas getting in and out freely does not discharge by its bur for intensities below 200° or 300° with angular distance of 30°. But at 500° or 600°, discharge comes on within and is then probably by a brush from that part.

3700. It is a good plan to connect i and ii when dividing, some little time, as half a minute or more, before taking the sample; and also to reconnect them immediately before taking the sample either of i or of ii.

3701. Positive electricity produces exactly the same results as Negative. In fact both are in the apparatus.

3702. *Air and Hydrogen.* AIR AND HYDROGEN.

i, Air . . . ii, Hydrogen
103° . .
102° . .
divided
50° . .
= 100°
. . 50°

3703. Again . . . .
. . 312°
. . 307°
divided
. . 154°
= 302°
148° . .

3704. Again . . . .
262° . .
261° . .
divided
132° . .
= 263°
. . 131°

AIR AND HYDROGEN. 3705. These very good results and shew that *Air* and *Hydrogen* are alike in their inductive forces.

NITROGEN AND OXYGEN. 3706. *Nitrogen and Oxygen.*

i, Nitrogen	ii, Oxygen	
309° . .		
294° . .		
309° . .		
	divided	
162° . .		
		= 327°
	. . 165°	

3707. This result too much and too serious—found I had left the conductor from which the apparatus was charged in a charged state, and that it had acted at a distance, influencing by induction the specimens taken. Again:

296° . .		
296° . .		
	divided	
147° . .		
		= 295°, very good.
	. . 148°	

3708. Again . . . .

	. . 411°	
	. . 410°	
	divided	
	. . 206°	
		= 413°
207°		
Discharged		
	. . 206°	
	divided	
105° . .	. . 110°	= 215°, too much.
102° . .	. . 107°	= 207°, not much out.

3709. Again . . . .

	. . 151°	
	. . 149°	
	divided	
	. . 76°	
		= 150°, very good.
74° . .		

3710. These results shew that *Nitrogen and Oxygen* are alike—I think that the stem of the carrying ball becomes a little charged near the ball in the first high charge, and that it retains a part of this in the second lower charges, so giving an amount of action in the two halves more than the first whole amount.

NITROGEN AND OXYGEN.

25 JANUARY 1837.

Nitrogen and Olefiant gas.

3711. i, Nitrogen ii, Oleft. gas

NITROGEN AND OLEFT. GAS.

On charging the ball, at first the repulsion of the two was 170°. Shall not[e] this for the future.

249° . .
120° . .
237° . .
239° . .
divided
119° . .
= 238°
. . 119°

A good result on the whole, but the variation at first shews the care wanted in making contacts, observing, etc. etc. I do not know what circumstance cause[d] that out of the way indication.

3712. Again . . . .

Balls at first 165°
. . 218°
. . 217°
divided
. . 110°
= 218°
108 . .

Good again. Hence these two gases are alike.

3713. *Carbonic oxide and Olefiant gas.*

CARB. OXIDE AND OLEFIANT GAS.

i, Carb. oxide ii, Oleft gas
balls 306
410° . .
405° . .
divided
201° . .
= 403. Good.
. . 202°

CARB. OXIDE AND OLEFIANT GAS.

3714. Again . . . .

balls 260
. . 340°
. . 337°
divided
. . 170°
= 338°. Good.
168° . .

Hence these alike.

CARBONIC OXIDE AND CARB. ACID.

3715. *Carbonic oxide and Carbonic acid.*

i, Carb. oxide ii, Carb. acid
balls—245°
330° . .
324° . .
divided
165° . .
. . 165°} = 330°. Good.

3716. Again . . . .

balls—160°
. . 204
. . 203
divided
. . 103} = 204. Good.
101 . .

Hence these gases alike.

OXYGEN AND CARBONIC ACID.

3717. *Oxygen and Carbonic acid.*

i, Oxygen ii, Carbonic acid
balls 250°
358° . .
345° . .
359° . .
358° . .
divided
179° . .
. . 179°} = 358°. Good.

3718. Again . . . .

balls 200
. . 282°
. . 276°
. . 276°
divided
. . 140°} = 278°. Good.
138° . .

Hence these gases alike.

3719. *Hydrogen and Carb. acid.*

HYDROGEN AND CARB. ACID.

i, Hydrogen ii, Carb. acid
balls 185°
267° . .
265° . .
divided
132° . .
. . 132°} = 264°. Good.

3720. Again . . . .
balls 187
. . 235°
. . 237°
divided
. . 119°
118° . . } = 237°. Good.

These gases alike.

3721. *Hydrogen and Olefiant gas.*

HYDROGEN AND OLEFIANT.

i, Hydrogen ii, Olefiant gas
balls 289°
390° . .
389° . .
divided
195° . .
. . 195°} = 390°. Good.

3722. Again . . . .
balls 270°
. . 357°
. . 355°
divided
. . 178°
177° . . } = 355°. Good.

These gases alike.

3723. *Oxygen and Olefiant gas.*

OXYGEN AND OLEFIANT GASES.

i, Oxygen ii, Olefiant
balls 165
222° . .
222° . .
divided
112° . .
. . 112°} = 224°, good.

OXYGEN AND OLEFIANT GASES. 3724. Again . . . .

balls 194°
. . 254°
. . 251°
divided
. . 126° } = 253°, good.
127° . .

These gases agree together.

OXYGEN AND AIR. 3725. *Oxygen and Air.*

i, Oxygen ii, Air
balls 94
267° . .
265° . .
divided
132° . .
. . 133° } = 265°, good.

3726. Again . . . .

balls 480
. . 663°
. . 622°
. . 615°
divided
. . 313 } = 624°; very fair for these
311 . .

high Nos.—but see the influence of the degree of charge retained by the shell lac support from the higher charge.

These gases agree.

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OXYGEN AND NITROUS GAS. 3727. *Oxygen and Nitrous gas.*

i, Oxygen ii, Nitrous gas
balls 280
. . 364°
. . 374°
divided
. . 202° } 402°, rather out.
200° . .

3728. Again . . . .

balls 210°
272° . .
273° . .
divided
139° . .
. . 141° } = 280°; very fair, but

both the quantities are above the mean—are the effects of the stem undischarged from a previous high number.

NITROGEN AND NITROUS GAS.

3729. i, Nitrogen ii, Nitrous Gas
balls 280
372 . .
372 . .
divided
187 . .
. . 187 } 374°. Good.

3730. Again . . . .
balls 225°
. . 314
. . 314
divided
. . 158 } 314°. Good.
156 . .

These gases alike.

NITROUS OXIDE AND NITROUS GAS.

3731. *Nitrous oxide and Nitrous Gas.*
i, Nitrous oxide ii, Nitrous gas
balls—235
335° . .
335° . .
divided
168° . .
. . 167° } 335°. Good.

3732. Again . . . .
balls 275
. . 375°
. . 375°
divided
. . 190° } 379°. Good.
189° . .

These gases agree.

NITROUS OXIDE AND NITROGEN.

3733. *Nitrous oxide and Nitrogen.*
i, Nitrous oxide ii, Nitrogen
balls
408 . .
420 . .
divided
. . 216° } 426°. Good.
210 . .

Is evident that the stem of the carrying ball acquires a little high electricity, which tells in the first low observation, which in fact is not halved.

NITROUS OXIDE AND NITROGEN.

3734. Again . . . .
Balls 335°
. . 455°
. . 458°
divided
234° . .
. . 232°} 466. Good again.

These gases agree.

3735. I think I must discharge the carrier ball each time, to get rid of this excess.

OXYGEN AND SULS. ACID.

3736. *Oxygen and Sulphurous acid.*

Found here, that the Sulphurous acid gas vessel did not insulate at all. Thought at first the gas was a conductor. But on filling the other vessel No. i with the gas, found it held its charge, and conclude therefore that ii is cracked in the shell lac—especially as, when filled with air only, it still will not insulate.

3737. With Suls. acid gas in No. i, had the following observations as to retention of charge.

At 9 h. 0 repulsion was 432° of torsion at 30°.
9.15 ,, ,, 375°
9.36 ,, ,, 336°
9.48 ,, ,, 315°
10.12 ,, ,, 263°
On now making the two balls of electrometer touch, the repulsion rose to . . . . 300°, then a fresh charge from i at
10.20 ,, ,, 430°
10.40′ ,, ,, 370°; making the balls touch and taking another sample from i at
10.41′ ,, ,, 430° again.

Hence the repelled ball of Electr. loses its electricity much faster than the apparatus does its charge.

3738. Left the apparatus all night. Next day, the 27th, recharged the balls from the apparatus and at 8.30 in the morng. the repulsion was 78°.

Very good insulation therefore by Sulphurous acid Gas.

31 JANY. 1837.

3739. Repaired App. ii with new stem of shell lac, and fixed it in with a little common cement. It then retained charge as follows, which will do, though not good:

At 4h. 15 = 480°
18 = 420°
25 = 375°

At 4h. 50′ = 330
5 10 = 303
5 30 = 275

3740. *Oxygen and Sulphurous acid gas.*

OXYGEN AND SULS. ACID.

i, Oxygen ii, Suls. Acid
balls 280
400 . .
395 . .
divided
. . 197 } = 392, good.
195 . .

3741. Again . . . .
balls 290
. . 420
. . 410
divided
207 . .
. . 207 } = 414, good.

3742. *Hydrogen and Sulphurous acid gas.*

HYDROGEN AND SULS. ACID.

i, Hydrogen ii, Suls. Acid
balls 360
525 . .
523 . .
divided
. . 261 } = 521°. Good.
260 . .

3743. Again . . . .
balls 370
. . 520
. . 525
divided
265 . .
. . 270 } = 535°

3744. When ii is first charged, the result of division is always a little higher than when i is first charged, but the difference is slight and depends not upon the gas, but the instruments, the capacities of which may very easily vary a little.

2ND FEBY. 1837.

3745. *Ammonia and Suls. Acid gases.*

AMMONIA AND SULPHUROUS ACID GAS.

Now filled i with Ammoniacal gas—found that it soon lost its charge; not instantly, but quickly. Could not decide whether it was from Ammonia rendering the shell lac a conductor, or from

AMMONIA AND SULPHUROUS ACID GAS.

a minute crack in the shell lac. I find that the difference of contraction between the shell lac and the metal rod in it causes solution of continuity in the former after a few days, and then it has to be replaced by new shell lac.

3746. As I could not charge the Ammonia apparatus, made the observation thus. Charged the Suls. acid app., observed the charge: then divided it with the ammonia app. by a quick touch and observed the Suls. acid apparatus again. The ammonia results are only put down to shew the rate and rapidity of loss of electricity. Of course the suls. app. would shew the state of both at the moment of contact or halving.

3747.	i, Ammonia		ii, Suls. acid gas	
		balls 200		
			. . 227	
			. . 220	
		divided		
			. . 117	× 2 = 234
	25 . .			

3748. Again . . . .

		balls 290		
			. . 408	
			. . 408	
		divided		
	158 . .			
			. . 204	× 2 = 408
	16 . .			

3749. Again . . . .

		balls 285		
			. . 395	
			. . 390	
		divided		
	150 . .			
			. . 200	
	Not 10 . .			× 2 = 400
			. . 200	

3750. The halved result when doubled is generally too high, but this may easily happen. If when both App. contain the same gas, contact is made for a moment between the charged and uncharged app., and then each is examined, they are not found alike, for the one originally charged is above the mean and the other under, and it requires a little time and two or three contacts before they become alike. This is probably due to the charged surface of the support not being able at once to throw off its electricity, when the charge by halving falls. The prolonged contact may not be allowed in the present state of the Ammonia apparatus, and hence the result above. But believe that it is like the other gases as to electrical capacity of induction.

AMMONIA AND SULS. ACID GASES.

3751. *Ammonia and Oxygen.*

AMMONIA AND OXYGEN.

	i, Ammonia	ii, Oxygen	
balls 320			
		438	
		435	
divided			
	145		
		220	× 2 = 440. Good.
or rather attraction	10		
(dischgd. it)		218	
divided again			
		110	× 2 = 220. Good.

3752. *Ammonia and Nitrogen.*

AMMONIA AND NITROGEN.

	i, Ammonia	ii, Nitrogen	
balls 370			
		530	
		524	
		520	
divided			
	176		
		263	× 2 = 526, good.
about	10		
(dischgd.)		263	
divided			
		133	× 2 = 266, good.

3753. *Ammonia and Hydrogen.*

AMMONIA AND HYDROGEN.

	i, Amm.	ii, Hydrogen	
balls 260			
		358	
		358	
divided			
	130		
		180	× 2 = 360, good.

3754. Again . . . .
. . 392
. . 390
divided
. . 195 × 2 = 390, good.
10 . .

3755. Now proceeded to fill ii with M. A. Gas—but then found that the apparatus discharged the electricity, almost instantly. Much faster than the Amm. app. i. Hence cannot compare them in this state.

3756. Opened i. The Ammonia good—the metal dimmed but not much acted upon. When all ammonia cleared away and the apparatus filled with Air, still it would not retain the charge; hence cause due to a crack.

3757. Opened ii. M. A. Gas good—action not much. When Air in the apparatus, still discharged as before. Hence also cracked. Must renew both and then probably find both insulate as well as the other gases.

15 FEBY. 1837.

3758. At Mr de la Rive's, who was to shew me the relative effect of a charge of acid and one of Sulphate of copper.

The battery consisted of 100 pr. of plates, $5\frac{1}{2} \times 5\frac{1}{2}$, of Cruickshank's construction, and therefore with single sides of the plates—and 30 pr. of 4 inch amalgamated Zincs in independant copper cells.

Acid charge	Sulc. Acid . . .	12 measured oz.
	N. Acid . . .	4 ,, ,,
	Water	2 gallons.

The battery gave a good spark with charcoal points—it heated about 9 inches of a certain sized iron wire red hot. About 10 minutes from the first charging, set it to decompose water (dilute S. Acid), and its action was such that it had evolved 20 measures of gas in $4\frac{1}{2}$ minutes, or 270 seconds, or a measure in 13·5 seconds.

After that the spark was poor and brief—there was no power of igniting wire, in fact it scarcely warmed it. No sensible discharging distance.

3759. In 25 minutes from the commencement, it could only set free 4 measures of gas from water in 230 seconds, or a measure in 57·5 second. Action then very low, and charge not acid to the taste.

3760. Now turned out this charge and washed the plates. Then re-charged with a cold saturated solution of sulphate of copper, to which 1 oz. of nitric acid per gallon was added.

The action was then exceedingly good—the ignition of charcoal magnificent and also that at the ends of silver cones—the vapour of the silver rose beautifully. The iron wire was ignited far better than before and the electricity was evidently very abundant.

3761. Tried the decomposing power on dilute Sul. acid—22 measures of gas were obtained in 165 second or a measure in 7·5 seconds!!

3762. After this, returned to the discharge at charcoal and other points: it was most beautiful. Above 2 feet of the iron wire could be well ignited in the open air. By opening the charcoal points, the discharge could be observed to take place even at the interval of an inch. By coiling the iron wire and putting it into a tube, 5 feet could be ignited.

3763. At an hour from the first action of this charge, again decomposed water; 22 measures of gas were obtained in 165 seconds or a measure in 7·5 seconds, exactly the same time as before.

3764. At 1 hour 40 minutes from the first charge of sul. copper, the spark seemed as fine as at first and the battery was evidently in fine action. On going down to the battery, I still found that there was sulphate of copper in solution in the charge and that the action would probably continue for some time longer.

3765. The results are very important and I should think the battery would have evolved 50 times as much electry. with this charge as with the acid charge.

3766. According to the strengths given
725 oz. of the sul. copper charge
would be equivalent to 49 oil Vitriol
and 725 oz. of the Acid charge „ „ „ 34·5 „ „
reckoning the N. A. added as oil vitriol.

3767. Hence the first might be supposed to surpass the second as 1·42 to 1. Probably however, the sul. copper charge can be more perfectly exhausted than the other, and therefore raise it to 2 : 1. Still this will not account for the difference.

3768. The effect depends upon the ready transmissibility of the current across the liquid in *each cell*, for whilst oxygen and acid can go at once to the zinc, the hydrogen is instantly disposed of without any serious impediment at the copper, and a clean copper surface preserved. It shews the value of removing resistance in the electrolyte, and that to do so is better than leaving it and increasing intensity of generating power at zinc plate.

3769. Probably not more zinc is destroyed in obtaining this magnificent effect, than with the poor effects of a common battery.

24 JULY 1837.

3770. Induction has no relation to any other property of matter than conduction and non conduction—perhaps it has no relation to conduction but only to non conduction. All conductors and all electrics charge alike and equally.

3771. *Induction.* Ascertain the forms of surfaces of equal inductive tension (as in expts etc.), *round a line electrified.*

round a circle plane
,, ,, square plane, at the diagonal
,, ,, cube
,, ,, hemisphere
,, ,, cone (as a point).

3772. *Electrical Axioms* (see Whewell, Vol. ii, p. 15).
There is no current of one electricity.
,, ,, charge without induction.
,, ,, such thing as an absolute charge with P. or N.
,, ,, difference of capacity } in Masses of matter.
,, ,, ,, induction }
,, ,, ,, current, Pos. or Neg.

3773. That there is no absolute charge of matter, either conducting or non-conducting, is very important in relation to chemical affinity.

3774. There is no charge without induction—and no current without both forces: they coalesce in a single result called the current.

3775. Charge is merely a tendency to current—current only a tendency to charge—the condition of insulation or conduction in the course is every thing as to whether the result is *charge* or *current.*

3776. As there can be no absolute charge of a body, so there is no development of one electricity—no property like capacity—no proof of real presence of an electricity, P. or N. All resolves itself into induction or tendency to a current. These strong proofs of the real equality of forces and natural identity of existence as opposed to the idea of two distinct fluids.

3777. These considerations also shew why in crystallization, chemical action and other actions of particles, we can discover no trace of electricity: the electricity is equal and local and expended in its place.

3778. All our tests depend either upon the current prolonged—

or upon induction at a distance. We want some effect of electricity to use as a new test of its presence and influence, when its action is limited, both in development and result, to a point.

3779. Unipolarity cannot exist. If there were such a thing as Unipolarity, then we could have a current of P. or N. alone, and all the principles above would be disproved. But as the current is always perfect in every part of its course, including elements both of P. and N., there cannot be unipolarity.

17 AUGUST 1837.

3780. Set about re-examining the Coloumb's Electrometer and the two induction air apparatus for the purpose of resumg. the experiments on induction in air, gases, etc.

3781. Found all as if loosing electricity fast and very irregular in action—found also the thin shell lac lever to which the repelled ball of Electr. is attached had softened by the warm weather, and bent a little, so that the ball was lower than proper for the graduation.

3782. Put a new shell lac stem or lever to this ball and a new support to the carrier or repelling ball. Then tried the retaining power of apparatus: the repulsion at the standard distance of 30° was at

5 h. 0′ = 148° of torsion
7′ = 129° ,, in 7′ loss was 19° or 2°·7 in 1 minute.
11′ = 122° ,, 4′ ,, ,, 7° ,, 1·7 ,, ,,
18′ = 116° ,, 7′ ,, ,, 6° ,, 0·8 ,, ,,
25′ = 110° ,, 7′ ,, ,, 6° ,, 0·8 ,, ,,

3783. The inductive apparatus i and ii were also tried and found to lose gradually—too much for use and yet not as if they were cracked. There are showers to-day and I suspect the effect of the damp warm air (weather very hot).

3784. Tried the Electrometer retaining power again, as above:

5 h 27′ = 330° of torsion.
30′ = 270° ,, in 3′ loss was 60 or 20° per minute.
35′ = 243° ,, 5′ ,, ,, 27 ,, 5·4 ,, ,,
45′ = 222° ,, 10′ ,, ,, 21 ,, 2·1 ,, ,,
6 3′ = 195° ,, 18′ ,, ,, 27 ,, 1·5 ,, ,,
10 40′ = 22° ,, 280′ ,, ,, 173 ,, 0·62 ,, ,,

18 AUG. 1837.

3785. Renewed examination of Electrometer (Coulomb's). I found that the pith balls did not conduct well; were in fact very bad conductors; and that the charge given to them was very uncertain by a sudden contact. They are now very dry, which is probably the reason of their difference now and before. Have therefore gilt these two balls (and also several other pith balls) and put them in their places again (wet under the gold). I have also put at bottom of Electrometer inside a glass dish with much Potassa fusa in it to *dry* the air, and have covered it over with a disc of wire gauze, to make induction every where alike.

3786. Now when the repelled ball, being charged, is touched by a wire, it can be discharged at once—the test of its fitness in that respect.

Again tried the retaining power (of Electrometer) as yesterday.

At 2 h. 18′ = 368° of torsion.

25′ = 352°	„	in 7′	the loss was	16°	or 2°·3	per minute.
35′ = 320°	„	10′	„ „	32°	„ 3·2	„ „
40′ = 309°	„	5′	„ „	11°	„ 2·2	„ „
50′ = 292°	„	10′	„ „	17°	„ 1·7	„ „
3^{h} 0′ = 275°	„	10′	„ „	17°	„ 1·7	„ „
10′ = 258°	„	10′	„ „	17°	„ 1·7	„ „
20′ = 239°	„	10′	„ „	19°	„ 1·9	„ „
30′ = 223°	„	10′	„ „	16°	„ 1·6	„ „
40′ = 206°	„	10′	„ „	17°	„ 1·7	„ „
50′ = 187°	„	10′	„ „	19°	„ 1·9	„ „
60′ = 174°	„	10′	„ „	14°	„ 1·4	„ „
4^{h} 10′ = 157°	„	10′	„ „	17°	„ 1·7	„ „
20′ = 144°	„	10′	„ „	13°	„ 1·3	„ „
30′ = 133°	„	10′	„ „	11°	„ 1·1	„ „
40′ = 122°	„	10′	„ „	11°	„ 1·1	„ „
50′ = 112°	„	10′	„ „	10°	„ 1	„ „
5^{h} 0′ = 102°	„	10′	„ „	10°	„ 1	„ „
10′ = 92°	„	10′	„ „	10°	„ 1	„ „
20′ = 82°	„	10′	„ „	10°	„ 1	„ „
30′ = 73°	„	10′	„ „	9°	„ 0·9	„ „
40′ = 64°	„	10′	„ „	9°	„ 0·9	„ „
50′ = 57°	„	10′	„ „	7°	„ 0·7	„ „
6^{h} 0′ = 50°	„	10′	„ „	7°	„ 0·7	„ „
10′ = 44°	„	10′	„ „	6°	„ 0·6	„ „
20′ = 37°	„	10′	„ „	7°	„ 0·7	„ „
30′ = 32°	„	10′	„ „	5°	„ 0·5	„ „
40′ = 27°	„	10′	„ „	5°	„ 0·5	„ „
50′ = 22°	„	10′	„ „	5°	„ 0·5	„ „
7^{h} 0′ = 18°	„	10′	„ „	4°	„ 0·4	„ „

19 AUG. 1837.

3787. Examined the inductive apparatus i and ii; find both are in bad insulating condition and want handles, i.e. shell lac stems.

3788. Put a new shell lac stem to i, and then tried it at intervals of two minutes.

At 28′	torsion force was	325°	loss of force	30°	per minute.
30′	” ”	265°	” ”	18°·5	” ”
32′	” ”	228°	” ”	10°	” ”
34′	” ”	208°	” ”	6°·5	” ”
36′	” ”	195°	” ”	5°	” ”
38′	” ”	185°	” ”	5°	” ”
40′	” ”	175°	” ”	4°	” ”
42′	” ”	167°	” ”	4°	” ”
44′	” ”	159°	” ”	2°	” ”
46′	” ”	155°	” ”	1°·5	” ”
48′	” ”	152°	” ”	1°·5	” ”
50′	” ”	149°	” ”	2°	” ”
52′	” ”	145°	” ”	2°	” ”
54′	” ”	141°	” ”	2°	” ”
56′	” ”	137°	” ”	2°	” ”
58′	” ”	133°	” ”	2°	” ”
60′	” ”	129°	” ”	1°	” ”
66′	” ”	123°	” ”	0·66	” ”
72′	” ”	119°			

Is moderate below 130°, but not good altogether.

3789. Now took app. ii, and taking out the shell lac stem, it was cleared from all the common cement (at the junction with the brass), then heated over spirit lamp and made soft and kneaded about so as to close all the cracks as far as possible. It was then refixed in the apparatus. Thus No. ii has been mended only, whilst No. i had had a new stem.

3790. The object was to ascertain whether a crack could in this way be obliterated, and the insulating power rendered good again. Now tried the insulating power of No. ii at intervals of two minutes, etc.

3791.

At 21′	torsion force was	383°	loss of force	6°·5	per minute.
23′	” ”	370°	” ”	9°	” ”
25′	” ”	352°	” ”	5°	” ”
27′	” ”	342°	” ”	2°·5	” ”
29′	” ”	337°	” ”	2°·5	” ”
31′	” ”	332°	” ”	3°·5	” ”
33′	” ”	325°	” ”	2°	” ”
35′	” ”	321°	” ”	2°·5	” ”
37′	” ”	316°	” ”	3°	” ”
39′	” ”	310°	” ”	2°·5	” ”
45′	” ”	295°	” ”	2°·6	” ”
60′	” ”	255°	” ”	1°·5	” ”
62′	” ”	252°	” ”	1°·8	” ”
67′	” ”	243°	” ”	1°·5	” ”
71′	” ”	237°	” ”	3°·2	” ”
75′	” ”	224°	” ”	1°·0	” ”
79′	” ”	220°			

3792. This is much better than i, but still it is irregular. Wiped the surfaces of the shell lac well, and this I have on former occasions found to be an important precaution.

3793. Now tried the instrument again.

[At] 47′	[torsion force was]	422°	[loss of force]	52°·5	per minute
49′	” ”	317°		14°·5	” ”
51′	” ”	288°	” ”	4°·0	” ”
53′	” ”	280°	” ”	7°·5	” ”
55′	” ”	265°	” ”	4°·0	” ”
57′	” ”	257°	” ”	2°·5	” ”
59′	” ”	252°	” ”	1°·5	” ”
61′	” ”	249°	” ”	1°·5	” ”
65′	” ”	243°	” ”	3°·0	” ”
69′	” ”	231°	” ”	3°·0	” ”
73′	” ”	219°	” ”	1°·7	” ”
77′	” ”	212°	” ”	1°·2	” ”
81′	” ”	207°	” ”		” ”

3794. This is worse than before, and also very irregular; hence some other cause for the loss of power. Yet it does not appear like a crack. Is perhaps dust or fine particles inside acting as carriers. Therefore opened the apparatus, wiped the inside carefully out with a silk handkerchief, put the apparatus together, charged highly and tried it as before.

App. ii.

3795. At 31′	torsion force was	734°	loss of force	44°·5	per minute
33′	” ”	645°	” ”	27°·5	” ”
35′	” ”	590°	” ”	8°·6	” ”
60′	” ”	375°	” ”	2°·5	” ”
4′	” ”	365°	” ”	3°·7	” ”
8′	” ”	350°	” ”	3°·0	” ”
12′	” ”	338°	” ”	3°·2	” ”
16′	” ”	325°	” ”	2°·0	” ”
20′	” ”	317°	” ”	2°·7	” ”
24′	” ”	306°	” ”	2°·c	” ”
28′	” ”	298°	” ”	2°·2	” ”
32′	” ”	289°	” ”	2°·2	” ”
36′	” ”	280°	” ”	2°·0	” ”
40′	” ”	272°	” ”	1°·2	” ”
44′	” ”	267°	” ”	1°·7	” ”
48′	” ”	260°	” ”	1°·7	” ”
52′	” ”	253°	” ”	1°·5	” ”
56′	” ”	247°	” ”	1°·5	” ”
60′	” ”	242°	” ”	2°·2	” ”
4′	” ”	233°	” ”	2°·0	” ”
8′	” ”	225°	” ”	0°·5	” ”
12′	” ”	223°	” ”	1°·0	” ”
16′	” ”	219°	” ”	1°·6	” ”
28′	” ”	200°	” ”	1°·4	” ”
45′	” ”	177°	” ”		” ”

3796. This will do very well. The importance of removing all small particles from within is well shewn by the result.

3797. Now returned to app. i. Took out the stem—cleaned its surface from common cement—refuzed the surface by spirit lamp flame—closed it up well—and replaced it, taking care of the common cement that it did not touch towards the ends (by the smallest particles). Wiped the outside shell lac well and then tried the apparatus again; it was as in the next page[1].

3798.

		App. i.
At 23′ torsion force was	438°	loss of force 43°·0 per minute
25′ ,, ,,	352°	,, ,, 6·0 ,, ,,
27′ ,, ,,	340°	,, ,, 5·5 ,, ,,
29′ ,, ,,	329°	,, ,, 8·5 ,, ,,
31′ ,, ,,	312°	,, ,, 1·0 ,, ,,
33′ ,, ,,	310°	,, ,, 4·0 ,, ,,
35′ ,, ,,	302°	,, ,, 1·5 ,, ,,
37′ ,, ,,	299°	,, ,, 2·5 ,, ,,
39′ ,, ,,	294°	,, ,, 3·5 ,, ,,
41′ ,, ,,	287°	,, ,, 3·5 ,, ,,
43′ ,, ,,	280°	,, ,, 3·0 ,, ,,
45′ ,, ,,	274°	,, ,, 2·5 ,, ,,
47′ ,, ,,	269°	,, ,, 2·5 ,, ,,
49′ ,, ,,	264°	,, ,, 1·5 ,, ,,
51′ ,, ,,	261°	,, ,, 3·0 ,, ,,
53′ ,, ,,	255°	

3799. This will now do, but is not so good as No. ii. Must remember that the repelled ball of Electrometer is also loosing the whole of the time; so that all the loss is not to be put down to the apparatus. Still, the result is probably very fairly expressed, because of the mode of taking samples from the app. at each observation.

3800. May now begin to halve charges on Monday, using ii as the app. to be charged principally, and i as the halving apparatus. The mode of proceeding is as before—to charge one app.—then charge carrier ball at the top of charged app.—to introduce the ball into the electrometer—to let the repel ball touch it—to observe the repulsive force at standard distance of 30° and enter it as "ball's force"—then to recharge carrier ball at app. and ascertain its force on repelled ball, doing this two or three times—then dividing the charge with the other apparatus, and observing the condition of one or both. The forces entered are degrees of torsion at the standard distance of 30° between the balls.

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[1] i.e. in the table which follows, par. 3798.

21 AUG. 1837.

3801. i, Air ii, Air
balls 134
238 . .
235 . .
232 . .
divided
117 . .
. . 118 } = 235, good.

3802. Again, ...
balls 160
. . 320
. . 310
. . 302
divided
. . 112 . . . . there must have been some want of contact here with carrier ball.
148 . .
. . 148 } = 296, good.

3803. *Air and Muriatic acid gas.*
i, Air ii, M. A. Gas
balls 118
230 . .
230 . .
divided
only 75 . .
. . 40
. . 40

This a bad result—the M. A. Gas seems to lose very fast—but whether by crack or action on the shell lac I do not know. Must take Air—then a momentary contact—then take Air again.

3804. i, Air ii, M. A. Gas
balls 78.
158 . .
156 . .
divided quickly
76 . . × 2 = 152 } good result.
77 . . × 2 = 154 }
. . 40

The M. A. Gas app. lets down charge very rapidly. Query why. The comparison with air still holds good, since at the moment of contact both app. must have been alike and at least 76° each.

3805. i, Air ii, M. A. Gas
balls 280
460 . .
440 . .
divided
218 . . × 2 = 436, good.
divided again
110 . . × 2 = 220, good.

3806. *Hydrogen and Muriatic acid gas.*
i, Hydrogen ii, M. A. Gas
balls 140°
280 . .
278 . .
divided
145 . . × 2 = 290 } pretty well.
142 . . × 2 = 282[1]
divided again
73 . . × 2 = 146—good.

3807. Again . . . .
balls 270
455 . .
415 . .
divided
216 . . × 2 = 432 } pretty well.
213 . . × 2 = 426
divided again
103 . . × 2 = 206—fair.

3808. *Ammonia and M. A. Gas.*

Filled app. i with Ammoniacal gas, dried over caustic potassa. Found it would hold no charge for a reasonable time—in 5 seconds nearly all charge gone and that in repeated trials.

3809. Cleared out the Ammonia—found the inside of the globe was not importantly acted upon; all the metal part was good. Took out the shell lac stem—refuzed it at the spirit lamp and replaced it. Then, on trying the apparatus, it appeared to hold its charge (having only air within). Refilled it with Ammonia and proceeded to observe.

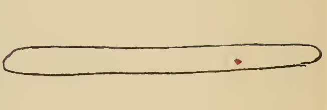
3810. i, Ammonia ii, M. A. Gas
balls 128
only 72 . .
then 30 . .

---

[1] Query 284.

The Ammonia app. will not hold the charge. It appears as if the surface of the shell lac were rendered a conductor by the contact of the ammonia. Took out the gas (Amm.) from the globe and inner ball, clearing all perfectly away. Wiped the shell lac (within) with a wet and then a dry silk handkerchief and then tried the apparatus, it containing only Air. It was a little better than before, but still very bad, and could not by further wiping make it better. Is permanently bad.

3811. A rod of shell lac was tried as to its insulating power on a charged gold leaf electrometer and found perfect. It was then put into ammoniacal gas for 10 minutes, after which it discharged the Electrometer *instantly*. Being wetted and wiped (which improve original shell lac), it was as bad as before; having been thoroughly spoiled by the ammonia. Hence the specific action of Ammonia on shell lac prevents it from being properly tried by this apparatus.



3812. Ammonia and shell lac is a case for consideration in conduction and probably analogous to the cases of chlorine or sulphurous acid in water—or of salts and acids in water, by which conducting power is somehow conferred.

3813. When the shell lac stem (rendered bad by ammonia) was heated at the spirit lamp, blisters rose on its surface under a thick and solid skin, the superficial parts not melting as pure shell lac does. This application of heat appeared to improve the insulating power, but by no means to restore it to its first state.

3814. Then scraped the surface of the shell lac, removing the whole of the surface. On refuzing the surface over a lamp flame, parts were observed still to froth—the scraping was repeated therefore (when cold) untill the whole of the surface was affected by heat as if pure shell lac. The stem was then replaced in the apparatus i and tried, air being within. It now held the charge pretty well and will do, I think, for chlorine, the next gas to be tried in it.

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3815. A piece of good insulating shell lac was put into chlorine gas—in 5 minutes it had lost its insulating power entirely—nor would washing and wiping restore it. It is of no use putting chlorine into the apparatus therefore, and the intention of trying it against

M. A. Gas } cannot be carried into effect.
Oxygen }
Hydrogen }

3816. Probably flint glass also would become a conductor in chlorine, from the oxide of lead in it.

3817. Chlorine and shell lac is probably a case of conducting power given by bodies not having it alone. For it is not likely to be due to M. Acid formed, as M. A. Gas in the apparatus does not take away the insulating power of the shell lac. Perhaps it does: see the results of the 19th with Air and M. A. Gas. If it does, this may be a mode of ascertaining whether M. A. is an electrolyte or not in its dry state, i.e. by effecting a sol. of it in pure Oil turpentine or Caoutchoucine or on shell lac, etc. etc.

3818. As App. ii very bad in insulating power—cleared out the M. A. Gas and washed all the apparatus. Scraped and heated the shell lac stem, but still when returned to its place the App. with *air* within would not hold its charge. Perhaps it was cracked. Then put a new shell lac to this App. ii, after which it held the charge pretty well. Now filled No. i with Arseniuretted hydrogen and No. ii with pure hydrogen, but on proceeding to experiment, found ii in a very bad state indeed—and very irregular in its apparent charge. The weather was rainy—perhaps the air might do something. Wiping the stems seemed to do good for a time, and then the good ceased. This went on for the whole day, and I left the apparatus at last thus:

No. i filled with Arsen. hydrogen—insulation bad.
No. ii ,, ,, hydrogen—insulation better than i but unsteady and uncertain.

3819. It is a question how far the showery weather interferes, with these irregular results. I must try a damp atmosphere within the balls.

3820. I am in doubt whether the carrier ball is right. From the dryness of air within the Electrometer, I think it has been thoroughly dried, and it now, from contraction of the surface gold and gum water, presents many irregularities of shape—small, but still they may affect the result. When the App. ii is charged only to 200°, the carrier ball held against it, at the end of its shell lac stem, vibrates from the brass ball into the air and back, and throws off brushes, etc. Hence it may retain a very uncertain charge.

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3821. Have had some new balls turned, of Alder wood; they are smoother much than pith. Have gilt them on the surface with gum water and they are now dry. Have taken one for use as a carrier ball and attached it to the proper shell lac stem—it is much heavier than the pith ball but will I think do well. Trying App. ii by it, it looked very well, the results being as follows:

At 30′	torsion force was	more than	720°	
40′	,, ,,	more than	720°	
70′	,, ,,	just	720°	loss 1·9 per minute.
140′	,, ,,		560°	

3822. Thus the carrier ball seems now good, and so also does the App. No. ii.

3823. Now tried No. i App. It was at first very bad in the insulation—but on opening it and wiping out the dust, it rose much in value and will do very well. It was at first above 920° and in 10 minutes after was very nearly 920°. Hence plenty of retaining power.

3824. I think many of the irregularities of the 22nd had been due to the form and condition of the carrier ball used at that time. Must never forget the serious influence of dust or fine particles within.

3825. Charged i with Arseniuretted hydrogen, ii being filled already with hydrogen.

Arseniuretted hydrogen and Hydrogen.

3826.

	i, Ars. hy.	ii, Hydrogen	
balls 165			
	. .	283	
	. .	280	
	. .	282	
divided			
	. .	141	283, very good.
	142 . .		

3827. Again . . . .
balls 290
390 . .
370 . .
divided
184 . .
. . 187} 371, good enough.

3828. Now filled i with Sul. Hydrogen (from M.A. and Sulrt. Anty.). The inside of i had been rendered black or grey black by the Arsenic combining with the metal. The tint was good and smooth and the state of the surface good.

3829. *Sulphuretted hydrogen and hydrogen.*
i, Sul. Hy. ii, Hydrogen
balls 270
. . 450
. . 450
. . 448
divided
. . 220} 435, fair.
215 . .

3830. Again . . . .
balls 200
297 . .
262 . .
divided
140 . .
. . 125} 265—good.

The two were connected again and then i taken immediately
130 . . × 2 = 260; this also good.

3831. *Fluo silicic gas and Hydrogen.*
i, Fluo Silic. Gas ii, Hydrogen
balls 100
. . 192
. . 190
divided
. . 96} = 192—very good.
96 . .

3832. Again . . . .
balls 58
85 . .
80 . .
divided
45 . .
. . 35} 80, fair; but some want of contact.

There was no second contact between trial of i and ii after first division. Whilst taking the observation of ii at the Electrometer, heard a crack, as of shell lac of App. i, and found that it appeared to have lost its insulating power.

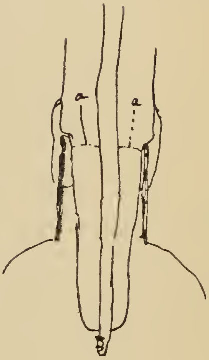
3833. Concluded the day's work by trying insulating power of i and ii again.

App. i has lost its power, can only retain a small charge.

App. ii was as follows:

At 50′	torsion	force was	220°				
52′	”	”	220°	loss of force was	0°·0	per	minute
56′	”	”	220°	” ”	0°·0	”	”
60′	”	”	218°	” ”	0°·5	”	”
64′	”	”	210°	” ”	2°·0	”	”
68′	”	”	208°	” ”	0°·5	”	”
72′	”	”	204°	” ”	1°·0	”	”
76′	”	”	200°	” ”	1°·0	”	”
80′	”	”	193°	” ”	1°·7	”	”
85′	”	”	187°	” ”	1°·2	”	”
88′	”	”	183°	” ”	1°·3	”	”
92′	”	”	179°	” ”	1°·0	”	”
96′	”	”	176°	” ”	0°·7	”	”

This is very good.



3834. It is to be remembered that a crack in the shell lac at *a*, where it always occurs, would freely discharge, because of its presenting the conducting power of a vacuum. It is almost as bad as if a piece of metal were suddenly put there.

3835. *Gymnoti.*

According to Sir Everard Home, the consul at Pará is John Hesketh, Esqr., and he can easily obtain gymnoti. John Moon, Esqr. is consul at Maranhán: he also can easily procure them and as he trades to England can also send them. He may be acted on through the Government.

3836. If Mr Kemp's expts. be correct, there must be some curious relation of them and also of endosmose and exosmose to the *nature* and *direction* of the Electric current. May also here have a relation or hold on the degree of chemical affinity. There must be some good principle active here. Will the effect vary with the substances in solution?

3837. With respect to Crystallization. Endeavour to carry crystallizing influence *by wires*, so as to set off as it were another solution, besides the active one—i.e. try *to transfer* the crystallizing force.

3838. Is *inductive intensity* the same for the same body, whether solid, liquid or gaseous.

3839. In discharges in insulating fluids, the particles charge and *travel.*

3840. The brush is a discharge of the same kind.

3841. Is not conduction referrable to a distinct act of discharge between neighbouring particles, and not any thing essentially different (to be called conduction).

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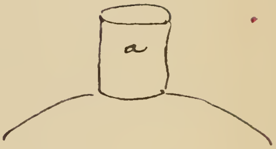
3842. Tested the Coulomb's Electr. (Potash within, etc. ( )), the day being very wet and stormy, the air damp, and the window close by left open on purpose.

At 30′	the torsion force	at constant	Chge. of 30°	was	692°			
34′	”	”	”	”	675°	loss	per minute	4°·2
38′	”	”	”	”	663°	”	”	3°·0
42′	”	”	”	”	655°	”	”	2°·0
46′	”	”	”	”	647°	”	”	2°·0
50′	”	”	”	”	638°	”	”	2°·2
54′	”	”	”	”	628°	”	”	2°·5
58′	”	”	”	”	616°	”	”	3°·0
2′	”	”	”	”	599°	”	”	4°·2
6′	”	”	”	”	583°	”	”	4°·0
10′	”	”	”	”	567°	”	”	4°·0
14′	”	”	”	”	552°	”	”	3°·7
18′	”	”	”	”	537°	”	”	3°·7
22′	”	”	”	”	522°	”	”	3°·7
26′	”	”	”	”	507°	”	”	3°·7
30′	”	”	”	”	492°	”	”	3°·7
40′	”	”	”	”	455°	”	”	3°·7
50′	”	”	”	”	420°	”	”	3°·5
60′	”	”	”	”	385°	”	”	3°·5
10′	”	”	”	”	355°	”	”	3°·0
20′	”	”	”	”	325°	”	”	3°·0
30′	”	”	”	”	300°	”	”	2°·5
40′	”	”	”	”	276°	”	”	2°·4
50′	”	”	”	”	255°	”	”	2°·1
60′	”	”	”	”	239°	”	”	1°·6
10′	”	”	”	”	223°	”	”	1°·6
20′	”	”	”	”	208°	”	”	1°·5
30′	”	”	”	”	188°	”	”	2°·0

Thus the charge holds very well for this wet day.

3843. The app. ii from which the Electr. had been charged at first had been left all this time undisturbed, but equally exposed to the damp air. At the close of the observations, i.e. 3 hours from the commencement, the repelling or carrier ball was charged at it again, and found to give a torsion force in the Electrometer of 250°, the electrometer balls themselves being given only 188°. Hence the App. ii holds charge better than the Electrometer, and both hold very well for practise.

3844. I have had the brass collar or socket (*a*) of the upper part of App. i, which was rather thick and thicker than that of App. ii, turned thin by Newman, so that the stem of shell lac will now be thicker there and the portion of metal will not be so thick, and therefore will not affect the shell lac in its heating and cooling so much as it did before. Expect to find the apparatus improved by this.



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3845. Began by trying whether Electr. and App. ii would hold their charges this morning.

At 35′ both were charged above 720° } Hence hold charge well
42′ both were still above 720° } for all I want.

3846. Now put pieces of wetted paper against the inside of the lower hemisphere of App. ii, applying them as flat as I could. When the apparatus was put together, this of course produced a humid atmosphere within. Proceeded to ascertain how this held charge in the usual way:

at 11′ the torsion force was	223°	
16′ ” ”	130°	loss 18°·6 per minute.
31′ ” ”	110°	” 1·33
36′ ” ”	105°	” 1·00

Thus rapid loss at charges 223°–130°—more moderate below 130° and not far from what might be expected. I found I could by no possibility charge the App. highly, the loss was so great at high degrees. However much it was charged, by the time I could take an observation (about 15 seconds) it had fallen to 250° or 260°.

3847. Here another result:

at 40′ torsion force was	255°	
41′ ” ”	125°	loss 130° per minute.
42′ ” ”	120°	” 5° ” ”
44′ ” ”	117°	” 1°·5 ” ”
50′ ” ”	109°	” 1°·3 ” ”

3848. Here again it holds pretty well at low degrees. I rather think the discharge at high charges is to the points of the paper, or other irregularities, on the inner surfaces, and not by the moist atmosphere or by moisture deposited on the shell lac. Took out the paper therefore, and left the inside metallic surface of the lower hemisphere damp. Then the results were thus:

at 55′	[torsion force was]		204°	loss	29°·6	per minute
58′	,,	,,	115°		1°·7	
68′	,,	,,	98°	,,		

3849. Thus still loses fast at high charges—not at low charges. Now wiped the lower hemisphere clean and dry, removing the little spots and lines of water which had formed—but the upper part and the inner ball were left untouched.

3850. Now at 12′5 [torsion force was] 560° loss 60° per minute.

14′	,,	,,	470°				
16′	,,	,,	395°	,,	37°·5	,,	,,
18′	,,	,,	340°	,,	27°·5	,,	,,
20′	,,	,,	285°	,,	27°·5	,,	,,
30′	,,	,,	170°	,,	11°·5	,,	,,

3851. Thus, takes far higher charges and is much improved, but still is not as before. The irregularities formed by the water have evidently caused much of the discharge, and perhaps others on the upper hemisphere and the ball may account for the rest.

3852. Now wiped out well both the upper and under hemispheres, and also the inner ball. This app. having been used for acid gases, the aqueous vapour had brought out by deliquiescence a roughness on these surfaces, which may have caused much of the discharge. *I did not* as yet wipe the shell lac stem within the hemisphere. Now results thus:

at 37′	torsion	force	705°	loss was	8°·7	per	minute.
39′	,,	,,					
41′	,,	,,	670°				
43′	,,	,,	665°	,,	2°·5	,,	,,
50′	,,	,,	630°	,,	5°·0	,,	,,
60′	,,	,,	585°	,,	4°·5	,,	,,
20′	,,	,,	500°	,,	4°·2	,,	,,
40′	,,	,,	440°	,,	3°·0	,,	,,
60′	,,	,,	380°	,,	3°·0	,,	,,
30′	,,	,,	312°	,,	2°·3	,,	,,

3853. It is now very much improved. So much that I conclude the deterioration was due to the numerous irregularities, caused by the sweating out of the salts from the pores of the metal. I think very minute irregularities upon the surfaces, though minute, still act as points and occasion loss, situated as they are in so mobile an insulator or transelectric as air is. The surface of the balls was very much improved in smoothness and appearance by the wiping.

3854. The aqueous vapour does not appear to have condensed on the shell lac or diminished its conducting powers sensibly.

3855. Now looked at app. i, which has had the brass collar turned thin (   ) and the shell lac stem repaired (   ). The shell lac is evidently cracked here and there; nevertheless fitted it into the apparatus by a neat collar of paper instead of common cement, as tightness was not now required. Its retaining power was as follow:

App. i.	At 26′	torsion force was	560°	loss was	45°·0	per minute.	
	28′	,, ,,	470°	,,	20°·0	,,	,,
	30′	,, ,,	430°	,,	8°·0	,,	,,
	32′	,, ,,	414°	,,	8°·0	,,	,,
	36′	,, ,,	382°	,,	3°·7	,,	,,
	46′	,, ,,	345°	,,	2°·5	,,	,,
	56′	,, ,,	320°	,,	1°·6	,,	,,
	86′	,, ,,	270°				

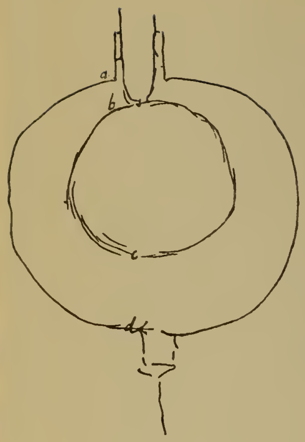
3856. Can here see the effects of the cracks at the upper degrees and then the discharge too free, but it may do for charges under 200°.

3857. Now experimented upon divided charges, both i and ii containing air at common temperatures, etc., and all things alike.

i, Air		ii, Air		
	balls 130			
	. .	219°		
	. .	218°		
	divided			
	. .	112° }	= 222° }	fair: a little too much.
110° . .		}		
	joined 110 × 2		= 220° }	

3858. Again . . . .

	balls 195		
325 . .			
322 . .			
	divided		
167 . .		}	= 330 fair: also a little too much.
	. .	163 }	



3859. Now shifted the stem of App. i upwards, so as to make the inner ball eccentric, the distance between *a* and *b* being as nearly as might be about one half what it was before and about one third of the present distance of *c* and *d*. It is evident that the quantity of air between the two balls remains unchanged, but that the distances, instead of being the same in every part, are greater in some and less in others. The question is, is the amount of action different? Is the capacity altered as to its whole sum?

3860.

Air i, Eccentric		Air ii, Concentric	
	balls 260		
		424°	
		424°	
		424°	
	divided		
		218°	= 420, good.
202°			
	joined 207 × 2		= 414, minus a little but good.

3861. Again . . . .

325°				
160°				
150°				
	divided			
85°			= 155°	Plus a little but very fair.
		70°		
	joined			
80°			= 155°	
		75°		

3862. Again . . . .

i, Eccentric		ii, Concentric		
	balls 110			
130°				
128°				
	divided			
70°			= 135°	Plus a little.
		65°		
	joined			
68°			= 132°	
		64°		

3863. Again . . . .

		174°		
		172°		
		170°		
	divided			
		87°	= 172°	Good.
85°				
	joined			
		84°	= 169°	
85°				

3864. Hence the displacement of the inner ball by this quantity makes no sensible difference in the inductive force: the sum of actions is the same.

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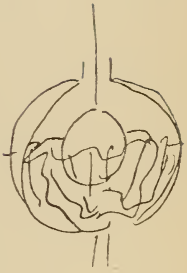
3865. *Caoutchouc.*

Used a sheet of Hancock's cut India rubber—found that when Gold leaf Electrometer was charged and touched by it, it insulated very fairly though not so well as shell lac. Then put a sheet in a crumpled condition into the lower hemisphere of App. i, so that when all together, it should intervene between the inner and outer ball at that part, being of course like a cup crumpled up there, and its parts at different distances from the 2 balls in different parts.



3866. i, Caoutchouc and Air ii, Air
balls 120°
. . 208°
. . 207°
divided
. . 103° × 2 = 206°, very fair.
80° . . i seems to be losing.
75° . .
. . 94° whilst ii holds well; the weather rainy.
. . 95°
52° . .
49° . . i evidently losing gradually, rather fast.

3867. Again . . . .
. . 400°
. . 400°
. . 395°
divided
. . 195° × 2 = 390°, good.
142° .
128° . .
110° . .
. . 188°
after some time
. . 182°
70° . . i losing therefore as before, but will do to shew that *India rubber is as Air.*

3868. *Silk handkerchief.*

Put a dyed silk handkerchief (clean, etc.) into the Apparatus i, and then tried its retaining power, but found it very small whilst silk in, returning to a moderate condition when silk out. Hence the dyed silk discharges, and I must use white silk.

3869. *Warm Air.*

Heated the outside of App. i by a spirit lamp so as to bring the brass up to 180° F. or thereabouts, whilst the App. ii remained cold. Then used the two apparatus in dividing the charge of one as before.

i, Warm Air ii, Cold Air
balls 300°
. . 540°
. . 528°
divided
. . 380° } 745°
365° . . } far too much.
joined 365° × 2 = 730° }

3870. There must be something here, if there be not a mistake in the first two Numbers. Can easily test the effect by taking the intensity of a cold charged apparatus, and then warming it: the intensity ought to rise: and if so, Bravo—what a result.

3871. The apparatus left as above, taken some time after and when i felt cool, though inside ball probably warm yet:

. . 330°
255° . .
255° . . then warmed i by application of spirit lamp, as before, but it did not rise, being only
220° . . loss rather therefore. Hence probably a mistake in the first numbers. Perhaps the Carrier ball lost part of its high charge in the air.
208° . . i is now losing fast—discharged it altogether and heated it, then:
. . 320°
. . 310°
divided
. . 156° × 2 = 312°, hence no change of capacity by heat.
85° . .
63° . .

3872. Now took App. ii; alone it gave

147°
145° . . being then heated by spirit lamp it fell to
127° . . this rather sudden, and there was no recovery on
cooling for 128° . . was the next, then
124°
124° . . so that here no signs of change of capacity by heat.

3873. Try the effects of heat again hereafter, and perhaps also upon some other body than air—a liquid or a solid.

3874. Testing experiments on retention all day long.

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3875. Tried insulating power of some fluids by dipping a glass rod in them and then touching a charged gold leaf electrometer with the wet part, the finger being also applied to the wet part about the third of an inch from the electrometer. Thus a film of the liquid of about half an inch long formed the communication.

3876. *Oil of turpentine*—good and filtered; *insulated well.*

3877. *Oil of turpentine*—old and with water at the bottom of the bottle; discharged the electrometer at once.

3878. *Naphtha (french)*—*insulated well.*

3879. *Oil gas liquid* — Do.

3880. *Caoutchoucine* —discharged moderately.

3881. *Cocoa nut oil* (the expressed solid part)—discharged at once.

Hence Oil of turpentine, Naphtha and Oil gas liquid appear as if they would do for transinductive media.

3882. Now arranged the two inductive apparatus and the Coulomb's electrometer, and having i half filled with Oil of turpentine and ii altogether with Air, proceeded to compare their capacities. Now found i lost charge almost instantaneously. Thought it might be by joint action of the shell lac stem and vapour of oil of turpentine, but on dipping a piece of shell lac in oil of turpentine, it did not discharge the excited Gold leaf electrometer.

3883. As the charge does not fall *instantly*, though very quickly, tried to make an observation by quick contact, halving if possible the charge of ii and then examg. ii to see what remained.

3884.

i, Oil turp.	ii, Air
balls 230	
. .	390°
. .	390°
divided	
. .	175 × 2 = 350—is less than 390 by 40.
divided again	
. .	79 × 2 = 158—is less than 175 by 17.
divided again	
. .	36 × 2 = 72—is less than 79 by 7.

Hence more than half goes away by contact and this looks like equality of inductive power, but is of course not satisfactory.

If less than half had gone, then should have had strong reason to believe that oil of turpentine had less capacity than air.

3885. As there is very large contact with the oil of turpentine in the inductive experiment, now tried its insulating power by gold leaf electrometer with equal extent of contact. Thus, put the lower hemisphere filled with oil of turpentine on to the gold leaf electrometer—diverged the instrument, and then dipped a ball into the liquid, the ball being 2 inches in diameter and held in the hand. When the ball just touched the fluid, there was scarcely a sensible discharge, but on further immersion the discharge was quicker, and when half in so quick as to interfere very much with my experiments. This is an excellent and the proper mode of trial.

3886. There was nothing particular at the surface of the fluid; the discharge was bodily through the oil of turpentine. *Must obtain purified oil of turpentine.*

3887. *Naphtha.*

Experimented with this fluid. Its insulating power, tried in the hemisphere, much better than Oil of turpentine, but still it does let the charge down. There is a little water at the bottom of the Naphtha bottle. Tried to divide the charge of ii.

3888. i, Naphtha ii, Air
balls 170
. . 296°
. . 295°
divided quickly
. . 133° × 2 = 266°
. . 135° × 2 = 270° } less than 295.
divided again very quickly
. . 62° × 2 = 124° less than 135°.

3889. The results are of the same general nature as those with the oil of turpentine—and liable to the same objection.

3890. Repeated the trial with a low charge of the app. ii.

3891. i, Naphtha ii, Air
balls 30°
. . 54°
. . 54°
divided quickly
. . 27°
. . 27° × 2 = 54°. A good result shewing equal inductive force.

3892. Again . . . .
Repelled Electrometer ball remaining as it was
. . 63°
. . 62°
divided, touching harder than before
. . 30° × 2 = 60°, very fair.

3893. This will do for Naphtha—unless I can obtain it in a better state.

3894. A piece of shell lac dipped into Naphtha has not its insulating power disturbed.

3895. *Naphtha* put into a bottle with pulverised carb. potassa to abstract the water, if any.

3896. *Oil of turpentine*—put into a bottle with fuzed chloride of lime and also quick lime, to abstract water, acid, etc.

3897. *Oil gas liquid.*

On trying its insulating power when in the hemisphere and touched by a large ball, it discharged the Gold leaf Electrometer at once, and will not do for the experiments.

3898. I thought I observed that as the liquid evaporated, it discharged the charged Electrometer, probably by its vapour particles assumg. the same state. But is worth pursuing in regard to the *production* or *dissipation of Electricity* by evaporating processes.

3899. *Caoutchoucine*—tried by hemisphere and ball; discharges too well.

3900. *Water*—far too well to allow of the least trial.

3901. *Silk.* Put a white silk shawl, folded many times, into app. i so as to be interposed there with the air. Found that though well dried and apparently insulating well when examined in the ordinary way, that now the large contact caused quick discharge of the gold leaf electrometer. Still, tried to obtain a result by halving the charge of app. ii, and then observing its condition.

3902. i, Silk and air ii, Air
balls 360°
. . 670°
. . 665°
divided
. . 280 × 2 = 560
. . 283 × 2 = 566
0° . . discharges very fast
divided again quickly
. . 130 × 2 = 260, not bad.

3903. Again . . . .
balls 42°
. . 70°
. . 70°
divided—a double touch and that disadvantageous.
. . 29° × 2 = 58°, very low.

3904. Again . . . .
. . 120°
. . 115°
divided
. . 57° × 2 = 114°
. . 58° × 2 = 116° } good.

3905. I think I may take it for granted that silk is like air.

3906. *Damp Air and dry.* Now tried these against each other, rendering the air of i damp by a film of moisture on the bottom of the lower hemisphere.

3907. i, Damp air ii, Dry Air
balls 280°
. . 470°
. . 475°
divided
. . 245°
225° . . } = 470°, good.
joined
. . 234° × 2 = 468°, good.
divided
. . 117° × 2 = 234°, good.

Hence damp and dry air alike.

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3908. Cast a hemisphere of spermaceti—it was very clear and good in quality. When tried by the gold leaf electrometer, having of course the large contact, it conducted even whilst still in the mould and warm. When cold it fitted into the lower hemisphere of the app. i, but the cavity within it was not quite large enough to receive the usual inner ball, but by a little scraping did very well.

3909. i, Spermaceti ii, Air
balls 263°
. . 440
. . 436
divided
. . 188 × 2 = 376—less than 436 by 60.
98 . .
85 . .
79 . . . . = 190° of torsion at interval of 20° only.

3910. Thus i with Spermaceti loses too fast for measurement at high intensity of charge but may perhaps take a lower intensity of charge and a smaller standard distance.

3911. i, Spermaceti ii, Air

balls 100° at standard distance of 20° for this expt.

i, Spermaceti		ii, Air	
	. .	164° 154	
	. .	160° 150	
divided			
	. .	70° 60 × 2 = 120°	too little, but evident that i loses fast.
46 56°	. .		
	. .	70° 60 × 2 = 120	
39 49°	. .		

Must however diminish all these readings by 10° because of the change of angular distance from 30° to 20°.

Have not time to pursue this now; but find that app. i with Spermaceti within will keep a charge equal to one inch divergence of the gold leaf Electrometer moderately well.

3912. *Gum copal*—a large tear; quickly discharged the gold leaf electrometer.

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3913. Have put a *new shell lac* stem to app. i; and as the brass cap or ferrel has been turned out thin, the stem is of some thickness there, and appears to be sound and good. On trying it by the gold leaf electrometer, it appears to insulate properly. Fixed the stem into the ferrel with a little collar of paper—used the medium or standard ball within and made a comparative expt. between i and ii as to insulating power.

i			balls at 430°	ii		
At 2^h 27′	. .	610°		At 2^h 26	. .	700°
			. . 12°			. . 3°
56′	. .	267°		57	. .	607°
			. . 2°			. . 2°·4
3 34′	. .	192°		3 34	. .	515°

3914. Thus i bad, but ii good in their present state.

3915. Now wiped the stem of i over every part very well to remove wax, etc. etc.

i			at 51′ alike	ii		
52′	. .	840°		53′	. .	877°
			. . 9°·0			. . 7°·4
59′	. .	778°		60′	. .	825°
			. . 6°·3			. . 3°·7
87′	. .	600°		80′	. .	750°

3916. Thus the power was very much improved by wiping, and perhaps wiping with a wet cloth would do more good—found that the carrying ball lost sometimes of its charge in passing through the air. Continued the comparison.

[i]			[ii]		
97′	564°	3°·6	100′	675°	3°·75
119′	482°	3°·7	120′	627°	2°·4
139′	428°	2°·7	140′	569°	2°·9
176′	370°	1°·6	178′	507°	1°·6
218′	290°	1°·9	220′	440°	1°·6
257′	228°	1°·6	259′	360°	2°·0
294′	200°	0°·8	296′	317°	1°·1

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3917. Returned to the apparatus. Wiped the stems well and prepared to experiment with different sized balls, etc. inside, to ascertain effect of circumstances and division, when capacity of the apparatus is really changed. Have had two other balls made—the different measurements are as follows:

Internal diameter of hollow sphere	3·57 inches
Diameter of usual or standard ball A	2·33
Width of intervening space	0·62
Diameter of smaller ball B	2·02
Width of intervening space	0·775
Diameter of large ball C	2·70
Width of intervening space	0·435
Internal diameter of the hemispherical cup D	3·20

3918. The app. i and ii is in very fair order; i moderate, ii Excellent. The day very fine. Put smaller ball B into app. i in the middle—App. ii having the usual standard ball A within it. Hence App. ii must have more capacity than app. i.

i, with Small ball	ii, usual ball	
balls 153°		
	268°	
	266°	
divided		
145°	142°	= 287°
rejoined		
148°	138°	= 286°
	135°	= 283°
rejoined		
145°	134°	= 279°

3919. Hence i must have a smaller capacity than ii.

3920. How is it that when i and ii, after being joined, are disjoined, i gives higher charge to the carrier than ii? ii ought rather to give higher charge than i, should it not?

3921.

i, with small ball B	ii, Usual ball A	
255° . .		
249° . .		
230° . .		
divided		
119° . .	. . 100°	= 219°
rejoined		
123° . .	. . 100°	= 223°

3922. Here also, when i charged and divided, still shews smaller capacity than ii. Here also i charges the carrier ball higher than ii.

3923. Again

i, Small ball B	ii, Usual ball A	
315° . .		
295° . .		
287° . .		
divided		
140° . .	. . 115°	= 255°
rejoined		
140° . .	. . 118°	= 258°

3924. Here i smaller capacity than ii, but gives *higher charge* to the carrier ball.

3925. A test of difference of capacity is supplied also by the difference of charge given to the carrying ball—for as the capacity of each differs, so they must charge the carrier differently when by its application to the external part it takes from them, altering their form and consequently inductive force there. The puzzle to me at present is that the one containing *most electricity* as having *most capacity*, gives the least charge.

3926. Again.

i, Small ball B	ii, Usual ball A	
balls 210°		
	. . 350°	
	. . 352°	
divided		
193° . .	. . 190°	= 383°
rejoined		
196° . .	. . 182°	= 378°
rejoined		
195 . .	. . 178°	= 373°

3927. Results as before. As difference of capacity can be thus easily shewn, it cannot have escaped me in the gases.

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3928. Now put the large ball C into app. i, making it concentric with the outer globe of the apparatus.

i, large ball C	ii, Usual ball A	
	balls 105°	
178° . .		
163° . .	i loses very fast	
153° . .		
143° . .		
133° . .		
divided immediately after last test taken		
87° . .	. .	× 2 = 174°
	. . 70	= 157°

i loses so fast I can put no confidence in it. Dismounted it—wiped all the parts and rearranged it with the same ball.

3929. i, large ball C; try its retaining power.

	balls 150°	
At 8′ was . .	248°	
10′ . . .	238°	. . 5°
12′ . . .	223°	. . 6°·5
14′ . . .	212°	. . 5°·5
42′ . . .	152°	. . 2°·1

3930. The loss is here very great. Now try for comparison app. i with the usual ball.

	i with ball A	
51′ . . .	211°	
53′ . . .	202°	. . 4°·5
55′ . . .	199°	. . 1·5
57′ . . .	191°	. . 4·0

Loses too much therefore with this ball also; and on examg. the stem at the point which holds against the brass, found a crack round it at that part. Must try to repair the stem.

3931. In many cases, the tension or charge seems to fall faster from a certain degree when the charge has been given just up to that degree, than when that degree has been attained by sinking from a still higher one. This effect indeed seems pretty general (4172, etc.). Therefore when a division is made of one charge into two, the two halved charges will sink with different velocities, though the apparatus may be equally good and retentive. Sometimes on halving, too, it seemed as if the uncharged could not receive its half instantly, or the other lose it; but that a second or third contact was required.

3932. Refuzed and repaired the stem of App. i, until it looked very well indeed, and then closed expts. for the night.

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3933. Wiped and Fixed repaired stem of App. i in its socket by a collar of white silk thread put round it as better than paper; attached the usual ball A to it and then tried retaing. power of both apparatus.

balls 340

i—with balls A in			ii, at 22′ both touched and alike		
24′	530°		26′	600°	
28′	353°	44°·2	30′	580°	5°·0
32′	275°	19°·5	34′	565°	3°·75
36′	237°	9°·5	38′	544°	5·25
46′	167°	7°·0	42′	536°	2°·0
			100′	384°	2°·6

3934. The alternate contacts of i and ii with the carrying ball of Electrometer must have taken from ii and given to i, so that part of the loss of ii has been from this cause. Between 38′ and 42′ there was no contact with i, and see the difference. It is very evident that i will not do. I must have a new stem of shell lac and without dirt in it.

3935. Marianini on passing of V. spark through flame (charcoal).
B. Univ. 1831, xlvii, 269.
Bellani's expt. with water and Mercy., Endosm. and Exosm.
Do. Do. p. 253.
Thermo electricity, cause of, Becquerel good. Do. 1832, xlix, 319.
Do. . . . Mincke (as in glass) etc. Do. 1831, xlvii, 137.
Is connected with Watt's solar compass, etc. etc.—interesting.

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Have cast some new stems from fresh shell lac.

3936. Have put *a new stem* to App. i, and have fixed it into the brass socket by a plug of silk. Now tried it against App. ii, after i had been well wiped and fitted with the usual ball A.

i		joined at 35′ balls 200	ii		
At 36′ was	200°		at 38′ was	238°	
40′	138°	15·5	42′	235°	0·75
44′	122°	4·0	46′	228°	1·75
54′	103°	1·9	56′	215°	1·3

3937. Thus i is very bad. Suspect the lac has cracked and that, like glass, it requires annealing. This the more likely as the substance hardens and softens by degrees and not suddenly.

3938. On rewiping and rearranging i and trying it again, it was much better in retentive power. Then thought that the discharge might have something to do with the loose filaments of the silk of the plug, and on using paper found the retentive power better. So resolved to fix it in with red cement as No. ii is fixed, and then there was a great difference indeed in the way of improvement. Whether this depends upon the absence of loose particles or upon closing the passage to air I cannot say; it would probably be right and instructive to search this matter out: but in fact i now retained charge as well as ii, as will be seen in the following results.

3939.

i		touched at 2′ balls at 360°	ii		
At 3′ was	628°		At 5′ was	625°	
7′	609°	4°·75	9′	607°	4°·5
11′	595°	3°·5	13′	593°	3°·5
15′	580°	3°·75	17′	572°	5°·2
25′	540°	4°	27′	538°	3°·4
35′	518°	2°·2	37′	512°	2°·6
45′	500°	1°·8	47′	484°	2°·8
1h 57′	478°	1°·8	1h 59′	455°	2°·4
3h 6′	370°	1°·56	3h 8′	334°	1°·7
40′	324°	1°·4	42′	278°	1°·6

3940. Now tried division of charge, Air being in both and the same sized balls, etc. etc. All alike.

i, Air		ii, Air	
	balls 92		
154°			
155°			
	divided		
84°		80°	= 164°, too much.
83°		79°	= 162°, too much.

As in some former cases, the halving app. is lower or gives lower charge to the carrying ball than the one originally charged, but the whole result is too much—as if i had more capacity than ii.

3941. Again . . . .

balls 200°
. . 363°
. . 361°
divided
178° . . . . 185° } = 363°, little too much.
174° . . . . 180° } = 354°

Here also dividing, app. i is lower than the other, ii, originally charged.

3942. i, Air ii, Air
285° . .
286° . .
divided at twice
143° . . . . 141° } = 284°, good.

3943. May conclude that division is good as an average result of several experiments.

3944. *Glass.* Have had the bottom of a flask (thin) well varnished with shell lac, to take away conducting power, and now put this cup into app. i, so as to ascertain if it had any influence on inductive force.

3945. i, Glass inside ii, Air
balls 250
430° . .
432° . .
divided at twice
217° . . . . 217° } = 434°, good.

3946. Again . . . .

. . 365°
. . 366°
divided at twice
182° . . . . 184° } = 366°, good.

3947. Hence this glass produced no difference.

3948. *Shell lac.*

Have cast a hemisphere of shell lac, so that it shall fit loosely into lower part of the apparatus i or ii. It is of shell lac which has been fuzed before and which contains therefore such impurities as dust, etc. etc.

3949. i, Shell lac ii, Air
balls 255
413° . .
404° . .
divided at twice
231 . .
. . 230° } = 461°—far too much. Apparently i has great capacity.

3950. Again . . . .
685° . .
650° . .
divided
365° . .
. . 362° } = 727°, same thing.

3951. Again . . . .
. . 358°
divided
. . 162° } 325°
163° . .

3952. Still indicates that i has more capacity than ii. Now this may be due to many small conducting particles in the shell lac. These would by a very simple action increase the capacity of that apparatus. I must use purified shell lac.

Spermaceti.

3953. The spermaceti hemisphere ( ) has been scraped until it fitted the interior of app. i, and was then introduced; touching of course the ball and hemisphere here and there by several points, and filling up moderately well the space between. The App. i with the spermaceti in seems to hold a charge moderately well.

3954. i, Spermaceti ii, Air
balls 225°
350° . .
330° . .
divided once
247° . .
. . 217° } = 464, over much.
joined again
235° . .
. . 228° } = 463, over.

3955. By this result, Spermaceti seems to have a greater capacity than Air—but this appears due to its conduction and its taking a charge on its surfaces as a conductor. As the conduction is feeble and slow, hence the reason why it is sometime before the final charge is fully taken or, on discharge, given up, time being required. Hence also the reason of certain irregularities in former cases, and hence a sluggishness and slowness in dividing the charge as seen above.

3956. Discharged the app. i; two or three minutes after, found a charge of 67° in it; and after a little while longer, of 80°. This had gone back to the discharged metal from the charged spermaceti.

3957.

i, Spermaceti	ii, Air	
	554°	
	583°	
divided once		
125°	218°	= 343°
joined		
144°	154	= 298°

This shews same result as the former; namely, an apparent high capacity for spermaceti—slowness of division—because of slowness of conduction.

3958. *Spermaceti* is a good slow conductor of Electricity if I should want one for the investigation of the manner in which *conduction* and *induction* are connected.

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3959. *Naphtha.* The Naphtha which has been standing on Carb. potassa since 6 Septr., on being poured off, was found to conduct better than before—being filtered, it conducted also too well. Being distilled, it was much improved and in its best state, but still did discharge when tested in a cup by ball contact and gold leaf Electrometer.

3960. *Oil of turpentine* from off lime and carb. potassa—is also much worse and appears to dissolve something. Being distilled, it was much improved and rendered even better than the Naphtha—but still does conduct and discharge.

3961. Tried App. i and ii, both containing air.

balls 360°

i		ii	
45′ was 540°		47′ was 535°	
	. . 2°·5		. . 2°·5
55′ „ 515°		57′ „ 510°	
	. . 2°·0		. . 2°·0
65′ „ 495°		67′ „ 490°	

Both in excellent condition.

3962. Now used the metallic cup or lining D ( ), which when in its place brings the inner metallic surface of the lower hemisphere of the apparatus containing it nearer to the central ball, the diameter of the hemisphere without the cup being 3·57 inches and with it only 3·2 inches—or the intervening space being diminished in that part from 0·62 of inch to 0·435. The lining was put into i, and ii left with usual distance.

3963. distance of half, 0·435 distance of whole, 0·62

i, with lining	ii, as usual	
	. . 475°	
	. . 469°	
divided		
227° . .	. . 225°	. . 452
joined		
223° . .	. . 219°	. . 442

3964. Thus i here has more capacity than ii, as would be anticipated.

3965. Again . . . .

467° . .		
460° . .		
divided		
238° . .	. . 230°	468°
joined		
235° . .	. . 225°	460°
joined		
225° . .	. . 222°	447°

3966. Here again i has more capacity than ii. The same thing occurs here, as at other times, that though repeated junction is made, one app. will give a higher charge to the carrying ball than another. Must search this out. The difference of capacity is not so much as I expected.

Again

3967. i, with lining . . . . ii, as usual
538° . .
517° . . i seems to lose fast—that is, however, natural and I must take the charge lower.
balls 235
382° . .
381° . .
divided
205° . .
. . 190° } 395°
joined
. . 194° } 394°
200 . .
joined again
. . 189° } 386°
197 . .

3968. All the results shew that i has more capacity than ii. i also always charges carrier higher than ii does.

3969. Now joined i and ii. Then took portions from each in alternate order, discharging the carrier ball each time. It is quite clear that the one of highest capacity ought then to give highest charge to the carrier.

i ii
187° . .
. . 179°
181° . .
. . 173°

Hence i higher capacity than ii.

3970. Again . . . .
balls as before
. . 302°
. . 296°
. . 297°
divided
. . 144° } 288°
144° . .

Thus i more capacity than ii, though ii charged at first.

3971. Then tried by charge of carrier ball:

i	ii
145° . .	
	. . 136°
142° . .	
	. . 134°

Again i the highest capacity.

3972. Considering that the difference of inductive capacity has been altered only in less than half of the interior of i, whilst the other half of i and the whole of the interior of ii and the external parts of the charged portions of both i and ii, i.e. the rods and small balls, all acting by induction, are unchanged; it was not to be expected that any great difference in the inductive force of i was to be expected.

Naphtha.

3973. Put the rectified naphtha into the lower hemisphere of i and proceeded to obtain, if possible, its inductive capacity (the inner lining had been removed from i).

i, Naphtha		ii, Air
	balls 200	
	. .	350°
	. .	344°
	divided	
	. .	113° × 2 = 226
scarcely any thing		

Thus this will not do—the Naphtha discharges too fast.

3974. Placed the Varnish glass cup in i and filled it with Naphtha nearly, so that the fluid might not touch both metallic surfaces, yet be in the place of the insulating medium.

3975.

i, Naphtha in Glass		ii, Air
	. .	324°
	. .	323°
	divided	
	. .	132° × 2 = 264
85 . .		
62 . .	loses too fast	

3976. Thus it is better, but still the Naphtha loses too fast; even if it had lost none, ii ought to have appeared low in charge, because of the effect of the Naphtha as a conductor taking a charge like the Spermaceti (   ).

3977. *Oil of turpentine*, the rectified fluid, tried in the same way, first in the hemisphere, then in the glass cup in hemisphere.

i, Oil Turpn.	ii, Air
	. . 267°
	. . 266°
divided	
	. . 120° × 2 = 240°
gone . .	

Thus conducts too well.

3978.

i, Oil Turp. in cup of Glass	ii, Air
balls 155°	
	. . 303°
	. . 295°
divided quickly	
	. . 138° × 2 = 276
68° . .	
46° . .	conducts too fast.

Found, however, that some of the turpentine had run over the glass cup and made extensive contact between it and the brass of hemisphere. This added to the conduction.

3979. Now tried i and ii; both containing air only.

i		ii	
at 8′ both above 310°			
balls 310°			
at 9′ was 276		at 11′ was 372°	
	. . 21·6		. . 0·8
14′ ,, 168		16 ,, 368°	

Hence i is in very bad condition since it has had the fluids in it—they probably affect the cement or shell lac.

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3980. i has been well wiped and exposed to air all night; being now tried, and after charging, joined, then

at 2^h 23′ both were much above 1000°	
3^h 0 both still above 1000	
4^h 16 i was 620	at 4^h 18′ ii was 930°
5 5 ,, 470	5 7 ,, 750°.

3981. Thus i was much improved by such airing. Again left it open to increase the good effect.

3982. *Shell lac.* Some shell lac which has been fuzed has been dissolved in spirit; and as it would not filter well, was left to clear by deposition, and though the wax would not settle, yet all dirt was in this way separated. The turbid uniform fluid was then evaporated in a jar to drive off the alcohol and a hemispherical cup cast—but it was evident that the heat had been applied too long, for the shell lac began to cling and set. However, such as it was, this shell lac hemisphere was tried.

3983.

	i, Shell lac	ii, Air	
balls 305			
		. . 523°	
		. . 523°	
divided			
	240° . .	. . 247°	= 487°
joined			
	237° . .	. . 242	= 479°

Here it appears as if i, or shell lac, had more capacity than ii or air.

3984. Again . . . .

?577° . .
670° . .
602° . .
640° . .

Think that these variations must be from variable discharge of the carrying ball at these high charges as it passes through the hole in the glass plate of Coulomb's electrometer—it perhaps being dampish from the state of the weather. Reduced the charge.

3985.

	i	ii	
	470° . .		
	475° . .		
	470° . .		
divided			
	252° . .	. . 238°	490°
joined			
	249° . .	. . 235°	484°
joined			
	239° . .	. . 227°	466°
joined			
		. . 226°	
	227° . .		
		. . 220°	
	226° . .		

Thus i has greater capacity than ii and seems to hold charge best. Hence is difference due to conduction; it is not to the conduction of the whole but of parts.

3986. Now shifted the Shell lac into App. ii.

i, Air		ii, Shell lac	
597° . .			
588° . .			
540° . .			
525° . .	loses rather fast—lowered the charge.		
370° . .			
364° . .			
	divided		
179° . .		. . 160°	} = 339°
	joined		
169 . .		. . 154°	} = 323°.

Hence it would appear that ii has more capacity than i app.

3987. As to the difference of charge given to the carrier ball when app. joined frequently. Suspect this depends upon permanent charge of the projecting part of the shell lac stem outside. Therefore discharged both apparatus by two or three successive touches with the fingers—and also the carrier ball—then i gave 17°—discharged ball again and then ii gave 4° or 5°—then ball discharged and tried alone on Electrometer gave 0°. Again dischgd. i and afterwards took specimen by carrier ball and found 12°. Hence evidently an interfering permanent charge.

3988. Now wiped the shell lac stem of i with a damp cloth whilst touching the brass so as to discharge it—then applied the carrier ball and now obtained 0°. Hence the electric condition of the stem is very influential in disturbing the results.

3989. Must try the retaining power of app. when the stem has been wiped with a *damp cloth.*

3990. Must try wiping the stem, as to its power of giving a charge to the carrier ball.

3991. Must ascertain if charging the app. by brushes from the excited glass rod charges the stem also.

3992. If so, must use a leyden phial to charge app.

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3993. Examined the retaining power of the shell lac stems when wiped with a damp cloth. The stems of i and ii were wiped at parts both in and out of the hemisphere, with very damp silk and *not* afterwards with dry silk—then both were charged and the charges equalized, using excited glass rod for the purpose held vertically over the balls.

touched at 25′
balls 246

i			ii		
at 25′	was above 432°		at 25′	was above 432°	
28′	„ 409		30′	„ 267	
33′	„ 370	. . 7·8	35′	„ 222	. . 9°0
38′	„ 341	. . 5·8	40′	„ 197	. . 5°·0

Thus both are bad, but ii the worst. As some time has elapsed, and both may have dried, recharged and joined.

3994. joined at 43′

43′	above 710°		43′	above 710	
44′	was 675°		46′	was 402	above 103°
49′	„ 509°	. . 33°·2	51′	„ 268	. . 26·8
54′	„ 435°	. . 14°·8	56′	„ 227	. . 8·2
64′	„ 370°	. . 6°·5	66′	„ 190	. . 3·7

Thus lose still and nearly as much as before.

3995. Now wiped the *outside* part of the stem of both with dry silk

joined at 10′

i			ii		
10′	above 630°		10′	above 630°	
11′	was 608°		13′	was 418°	. . 71°
16′	„ 518°	. . 18°	20′	„ 290°	. . 18°·3
21′	„ 485°	. . 6°·6	23′	„ 259°	. . 10°·3

3996. About as before. So that *dry wiping* the outside part of the stem *has not* improved retaining power.

3997. Now dry wiped the inside part of the stem also, or that portion within the hemisphere

joined at 38′

38′	above 475°·4		38′	above 475°·4	
39′	was 472°		41′	was 470°	
44′	„ 455°	. . 3°·4	46′	„ 457°	. . 2·6
49′	„ 420°	. . 7°	51′	„ 440°	. . 3·4
59′	„ 385°	. . 3°·5	61′	„ 415°	. . 2·5

3998. Thus both greatly improved by inner dry wiping, especially ii. i falls rather too fast: it still retains a smell of oil of turpentine which I must drive off, and clear away. Good also to wipe up the stems inside of the socket.

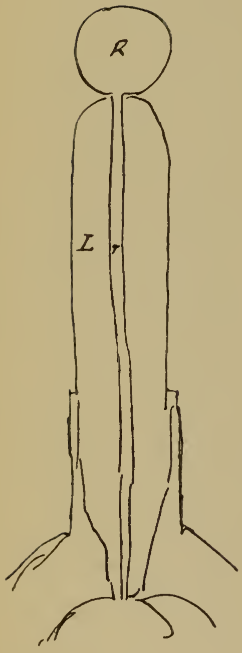
3999. Now *discharged* both at 5′ and then tried what charge they could still give to the carrier ball

i			ii		
at 6′	was	30°	at $7\frac{1}{2}$	was	18°
9′	”	35°	” $10\frac{1}{2}$	was	19°
discharged both again at 47′—then gave					
at 48′	”	12°	at 49′	”	2°

4000. Thus they hold a charge when every thing seems proper for their complete discharge.

4001. Found that touching the carrier ball freely and readily discharged it, for it did not then disturb the indicating ball of Electrometer: so that the effect observed could not be due to any effect of its electrified stem.

4002. Wiped the shell lac stems of i and ii outside with damp silk and then found that i could give a charge to the carrier ball of not more than half a degree and ii no charge at all.



4003. Hence this effect, which has so often mingled its disturbing influence with other results, is a consequence of the excited state of the outside of the shell lac stem: and, by the force of induction, retaining the metal near it in a charged state, *though uninsulated.* This state is probably brought on thus: R and its wire *r* is charged Pos. and acts by induction through the shell lac L as well as elsewhere. If the air next L were perfectly clean, this would be an unchanged action for the time, and easily discharged, but particles of conducting matter floating in the air are drawn towards surface of L and gradually communicate a charge to it, which has then an equivalent portion of the induction of *r* directed exclusively towards it. When R and *r* are discharged afterwards, this portion of the effect can not be discharged until the surface of the shell lac has been touched by uninsulating matter, etc. etc.

4004. Proceeded to ascertain what effect as to excitement of stem would be produced by wiping them with dry silk. Both i and ii being discharged well, then had a good wiping and rubbing of the stem with dry silk, the brass ball above being at the same time touched above to assist by allowing induction. $\therefore \left.\begin{array}{l}\text{i gave } 5^\circ\\ \text{ii gave } 7^\circ\end{array}\right\}$ to the carrier applied as usual at the top or summit of the ball.

4005. Then discharged them by wiping first with a damp silk and then dry silk, so as not to excite the stem. After that, charged i from the Excited rod and discharged it again immediately by hand, and then applied the carrier ball to see what effect the short charge had produced—it equalled 3°.

4006. Charged i very highly for 2 or 3 minutes, then discharged it and found carrier ball indicated residual charge of 10°. Discharged conducting part again, but on again applying carrier ball it still gave 10° (Pos. always).

4007. Was now charged and left for 15 minutes, and then being discharged, gave residue to carrier = 12°. On taking sample by carrier whilst the finger was actually in contact with the brass ball R, so that no doubt of its uninsulated condition could remain, still the charge was 14° Pos.

4008. Now held carrier ball about $\frac{1}{3}$ of an inch from the *side of the shell lac* stem—uninsulated it there—then insulated it, and found it to give 60° Pos.

4009. The charge of the shell lac is never derived from the excited glass rod used in charging the apparatus. When this was approached sideways to the ball R, the shell lac stem *could* be charged by it—but then on discharging the apparatus and trying the electricity communicated to the carrier by ball R, it was found to be Negative—as was to be expected. It shews that the other and residual charge is from excitation of the stem in the manner described or by wiping (   ).

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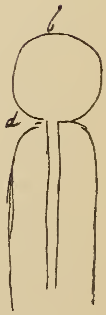
4010. Tried app. i and ii with Air in both.

i			ii		
touched at 58′					
at 58′	above 980°		at 58′	above 980°	
59′	was 930°		61′	was 965°	
22′	„ 508°	. . 18°·3	24′	„ 750°	. . 9°·3
27′	„ 463°	. . 9°·0	29′	„ 725°	. . 5°·0
34′	was discharged, then gave 11°		36′	was discharged—gave 8°	
	again dischgd. „ „ 12°		48′	Do. „ 5°	
At 53′ carrier ball was applied at *d* whilst finger touched at *b*—the charge was 88°.			At 52′ carrier ball at *d* whilst finger at *b*; received charge of 22°.		



4011. Cast a new hemisphere of the best shell lac—sifted and cleaned but not dissolved in alcohol.

4012. Also opened app. i and found the stem cracked in several places. *Repaired it by softening and fusion* over the spirit lamp and then restored it to the app., so as to put all into working condition again.

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4013. Now tried and tested retaining power of i and ii.

i				ii		
			joined at 15′ balls 190°			
at 17′	was 510°			19′	was 135° only	
			rejoined i and ii at 21′			
22′	,, 328°			24′	,, 190°	
27′	,, 307°	. . 4°·2		This app. bad in retaining force; wiped it well and recharged it separately.		
32′	,, 295°	. . 2°·4				
37′	,, 291°	. . 0·8				
42′	,, 285°	. . 1°·2				
52′	,, 262°	. . 2°·3		at 29′	,, 540°	
				34′	,, 510°	. . 6·0
				39′	,, 495°	. . 3·0
				44′	,, 476°	. . 3·8
				54′	,, 448°	. . 2·8

4014. Both will now do. They were discharged at 56′ and then found as follows with respect to the retained charge.

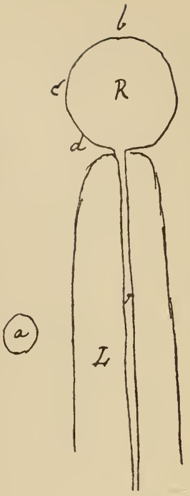
. . . 10° . . . 16°

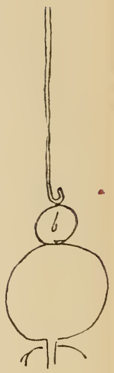
4015. To avoid as much as may be this interfering charge of the stem, I must use only low charges in the apparatus and work in a *quiet* clean atmosphere. Wiping each time is needful. I have often found discharge of a gold leaf electrometer come on suddenly and have been able to trace it to invisible films (of spider's web perhaps), for I have been able by slight blowing to restore insulating condition, and that has happened over and over again in the room whilst making these experiments.

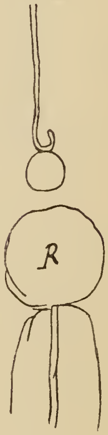
4016. It seems to me that good proof of induction in curved lines can be obtained in these effects of induction from stem and that such action in *curved lines* is a better test of *molecular action* than Specific capacity will be.

4017. Inductive action of stem and that action in *curved lines*.

4018. Charged ii as usual Pos.—then touched the outside of the shell lac in several places with the fingers, so as to let it take up a charge by induction—then discharged R and all the metallic part. Placed carrier ball at *a*, touched it—insulated it, removed it and found it gave Pos. repulsion 230°.







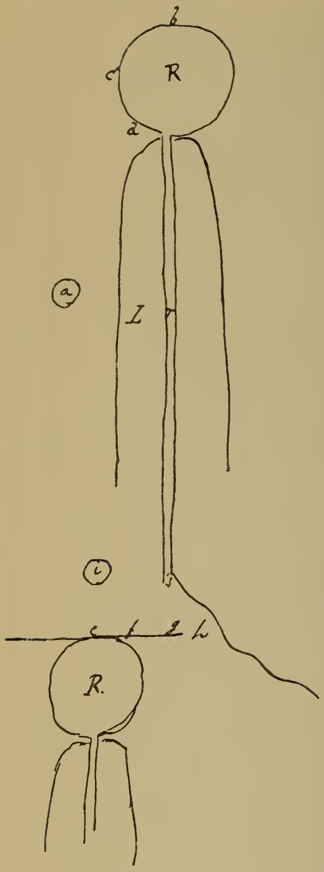
4019. Discharged the carrier—placed it at *b*—touched it with uninsulating wire so as to bring all to quiescent state—removed first the wire and then instantly the carrier ball, and found it 20° Pos. Then discharged the carrier and re-applied it at *b*, not touching it this time with the uninsulating wire, so that I might obtain the effect of the return of charge to the ball R, etc. in the two minutes elapsed, by the spontaneous lowering of the charge on the outside of the shell lac stem—found the charge now 25° Pos.

4020. Again placed it at *b* and uninsulated it as before for a moment, and now found it 19°. Hence this charge of 19° is not the effect of a return towards ordinary charged state, but is due to induction from surface of shell lac towards R at *b* whilst R is in connection with the ground. Hence is induction round a corner or at least in a curved line.

4021. Now held the carrier ball a little way off from R at *b*—touched it—insulated it and found it gave 17° Pos. Hence the effect is the same in kind and almost in degree as when it *touched* R at *b*. The cause of the state acquired in the two situations is the same therefore and is not due to the electric state of the ball R, which would have given one kind of Electy. by contact and the other by induction.

4022. I held my hand round the shell lac stem, at a little distance, to divert the inductive force, touching R at the same time. I then insulated R, and removing my hand from round the stem, expected to find R at *b* Neg., because of the return of inductive influence on to the wire stem inside it: but now the carrier applied there was Pos. to the amount of 8°; being less than before but still Pos. Hence some other influence—perhaps that inside in the lower part of the apparatus. I must separate R and its wire from the inductive part of the apparatus below. There is of course always an effect of a similar kind going on inside unless the wire of R be UN*insulated*.

4023. Must in future expts. of division of charge thoroughly



uninsulate the outsides of app. i and ii. I suspect the mahogany table interferes a little by its polished and badly conducting state.

4024. Rearranged and made table conduction and discharge perfect by sheet of tin foil connected with the bell wires of the house.

4025. Now arranged the apparatus, and after having brought the outside surface of the shell lac into an excited state, adjusted matters so that the wire *r* and its ball R were in connection with the ground; *wire uninsulated.* Then proceeded to experiment.

4026. Carrier ball at *a*—uninsulated by a wire—insulated—removed; gave 80° Pos.

Observation repeated—ball at *a* being now touched with a finger: was 65° Pos.

Carrier ball at *b* gave 10° Pos.
Carrier ball at *c* gave 17° Pos.
Carrier ball at *d* gave 52° Pos.

4027. Now put a tin foil plate, the size of half a crown, upon R and took observations on its upper surface.

Carrier ball at	*e*	took charge of	5° Pos.	all Pos.
,, ,,	*f*	,, ,,	5° ,,	
,, ,,	*g*	,, ,,	5½° ,,	
,, ,,	*h*	,, ,,	8° ,,	
,, ,,	*i*	touched, etc. etc.	4° ,,	

4028. Found I could always easily discharge the carrier ball perfectly—the effect is not from electricity retained by its stem but from state of R and its associated parts, and being always Pos., is always an effect of induction from outside of stem L. The induction is strikingly round a corner in this case.

4029. This inductive influence seems like an action of particles, *different* in its nature and kind from that of gravity; for it is a power acting in curved lines, i.e. by intermediate particles. It is also a satisfiable and *limited* power, for a particle *m* acting towards *n* or *o* with a certain amount of power cannot act with the same power towards both at once—in that respect is like its dependant conditions of power, Magnetism and chemical affinity.

4030. The apparent Capability of bending the influence in many common experiments, as drawing of sparks, brushes, seems to shew the same thing: but must here distinguish between effects of current, as spark, brush, current of air, etc. etc. and the prior inductive condition. The current or discharge effects are undoubtedly connected with molecular action. I believe the prior inductive effect is also.

4031. The discharge round the edge of glass is not conclusive perhaps, though that admits of an argument, but the induction round the edge of a metal, I believe, is.

4032. The repelled ball of Electrometer should not be too highly charged in these experiments. After causing the repelled and the carrier ball to touch per force observed their repulsion (always at 30° of interval unless otherwise expressed), and it was 55°. Then repeated expt. (4025).

Carrier ball at *a*	. . .	210°	
,, ,, *b*	. . .	24°	
,, ,, *c*	. . .	46°	
,, ,, *d*	. . .	162°	
then tin plate on R			very striking results.
,, ,, *e*	. . .	10°	
,, ,, *f*	. . .	11°	
,, ,, *g*	. . .	16°	
,, ,, *h*	. . .	29°	

4033. Now the balls being as supposed about 55°, tried the power at *b*: it was 20°. Then diminished the electricity of balls so that repelling power between them was less than 10°, and now specimen from *b* gave only 8°. Hence state of electrometer repelled ball too low.

4034. Made the mutual repulsion of electrometer balls after contact 34°, and now a specimen from *b* was 22°. So that apparently a charge between 35° and 60° of the electrometer balls may be a good condition of them for experiments where the charge of the carrier is to be about what is [? it] is here.

4035. Continued the experiments.

balls	. .	35°	
Carrier ball at *a*	. .	47°	
,, ,, *b*	. .	7°	
,, ,, *c*	. .	14°	
,, ,, *d*	. .	70°	
,, ,, *e*	. .	3°	with tin foil plate on.
,, ,, *f*	. .	3°	
,, ,, *g*	. .	5°.5	
,, ,, *h*	. .	7°	
,, ,, *d*	. .	35°—hence stem is losing fast and wanted wiping.	

4036. Wiped the stem, etc. recharged, etc. and restored things to the condition of R, and *r* its wire being uninsulated as before. The balls are 35° or lower.

Carrier ball at *a*	65°	balls 35° or lower.
b	7°½	
c	14°	
d	60°	
a	127°	balls had now been made 85°.
b	12°	
c	23°	
d	114°	
b	14°	balls had been made 114°.
c	26°	
d	132°	
a	97°	

Even up to this height therefore of 114°, it is good and an improvement.

4037. The best charge of Electrometer for small degrees will hardly be the best charge for the large degrees: but there must have been some mistake about the effect with the repelled ball charged very low.

4038. Must see what the wire of R does.

4039. Now discharged the metal stem and all, and put up the apparatus in the ordinary way, when of course R, *r* and the large ball beneath within were insulated: then examined to see if anything remained. The carrier ball at *b* gave no signs or if any a little attraction—when applied at *d*, it gave slight traces of a charge = 3° Pos.

4040. Charged the apparatus in the usual way from excited rod:

at 0′ was	528°	11°	
5′ „	473°	10°·6	loses fast.
			at 7′ a charge taken at *d* gave 545°. The surplus effect is induction towards the outside of the stem.
10′ „	420°		
15′ „	395°	5°	

4041. Now discharged the apparatus, i.e. the metal R, etc.; then the carrier ball at *d* gave 115°, and at *b* 9°. Half an hour after, discharged R again, and then *d* gave 90° and *b* 9°.

4042. App. ii seems not to insulate well, but very probably there is dust inside, for it has been opened and handled much.

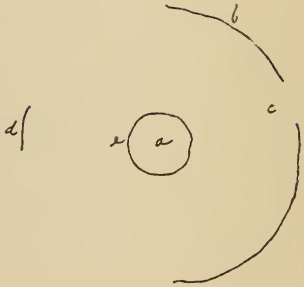
4043. Must repeat these experiments with solid shell lac stem. Must avoid currents of air upward—must use different positions—must warm electrified globe, it being uppermost. Must interpose glass or mica and see if influence still be round a corner.

4044. Can try in oil of turpentine; but that a conductor.

4045. *Conduction and Induction*—their analogy: transition and condition quite in favour of the particle view.

4046. As there is no difference of transinductive force, so I can produce no effect of bending by different arrangements of transelectric bodies. But it will be as well to try the interposition of glass and air between inducing and induced ball.

4047. Suppose *a* an electrified globe of metal and *b* part of a concentric sphere with a hole at *c*—*d* being a disc rather smaller than *c*. Then let *b* and *d* be in contact with the earth; *d* would take up a certain charge—or if placed in *c* it would also take up a charge, but in the second case the charge would be less than the first. Even if *a* were a globe of glass or shell lac, so that the electricity with which it was charged could not move on its surface so as to accumulate at *e*—the effect would be the same. Now this is most likely an effect of action in curved lines; but it might be argued that more straight lines would be determined from the *side* of *a* at *e* towds. *d* when as now placed, than when at *c*. Hence the necessity of having a stricter experimental proof than this in the first instance.



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4048. Charge of clouds. How do they become electrified if there be no absolute charge?

4049. No charge from breaking up sulphur or change of state.

4050. Nature of discharge through cracks in glass.

4051. Is Fischer's observation on variation of conductibility of platina sound or no, and if it is, what bearing will it have on thermo-electricity? Bib. Univ., 1831, xlvi, 267.

4052. Matteucci—expts. on Evaporation of water from a soil as a source of Electricity. Bib. Univ., 1834, lvi, 328.

4053. *Thermo electricity*. Is it possible Peltier's experiment (Bib.

Univ., 1834, lvii, p. 181) can be true, i.e. that a thermo electric current produced such an effect elsewhere as to create an opposite current *greater* than the original?

4054. Electricity in motion penetrates bodies. Statical Electy. does not, but is superficial. The reason of this is evident on the particle action theory without breaking in on a law or requiring a new one. Before the conduction took place and after the communication was completed, both insulating and conductive particles were polar—but one can equilibrate or discharge more than the other.

4055. *Induction*—Nobili has some general facts in very good relation to induction. Bib. Univ., 1835, lix, pp. 275.

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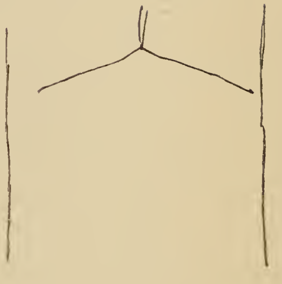
4056. As the Alcohol shell lac does not dry except very slowly and is soft and conducts, I to-day reheated it carefully in a porcellain basin, melted and stirred it much until far more of the Alcohol had been dissipated, and then recast it as a hemisphere. The driving off the last portions of the Alcohol is very difficult without injuring the shell lac, for the shell lac will not fuse throughout, but softens only in one part whilst it runs the risk of burning in another part.

4057. When cold, found that, as tested by the gold leaf Electrometer, the hemisphere appeared to insulate well and will probably answer every purpose.

4058. Wiped and arranged i and ii on the discharging table.

4059. Now mean to use a little Leyden phial to charge the apparatus'. It charges up about enough with a dozen passes of the excited rod, and when it opens the large gold leaf electrometer thus, is sufficiently charged to charge the app. i and ii from.



4060. Charged ii with the jar. Then charged the carrier ball from the Leyden phial, and with it charged as usual the repelled ball of Coulomb's electrometer. The balls gave 80°. App. ii gave 135°; left it 8′ or 9′ and discharged it, when the residual state at *b* gave 5° and at *d* gave 41°.

4061. Think that one of the two following forms of proceedure will be better than that I have employed. Suppose i electrified and ii to be used in dividing the charge.

a take the balls.
b ,, ii—if possible so thoroughly discharged that it shall give 0°.
c ,, i.
d ,, i again.
e divide charge and instantly after take ii.
f take i as quickly as may be—for comparison's sake.
g discharge ii and take residual effect.
h discharge i and take residual effect.

Then *e* ought to $= \frac{d-h}{2} = f-h$; i.e. *e* or $f-h$ ought to be half charges of the transferable whole charge, $d-h$.

4062. *Second form*

a take the Electrometer balls.
b take ii as before thoroughly discharged = 0°.
c take i.
d take i again.
e divide the charge and instantly after take i.
f take ii as quickly as may be (for comparison).
g then discharge i and take residual effect.
h discharge ii and take residual effect.

Then $e - g$ should equal $\frac{d-g}{2}$: it should also equal *f* if the latter has undergone no change, or $f +$ a little if it has. Perhaps the first form is the best.

4063. Now experimented with Air in both apparatuses.

		i, Air	ii, Air	*Second form*
	a	balls 160°		
at 54′	*c*		. . 275°	
	d		. . 268°	
time 8′		divided and immediately after took		
	e		. . 139°	
	f	125° . .		
	g		. . 16°	after being discharged.
62′	*h*	0° . .		after being discharged.

Here $139 - 16 = 123$, whilst $\frac{268 - 16}{2} = 126$—but the continual loss during the whole of experiment being taken into account will make the difference less. The difference between $139 - 16 = 123$, and 125 or *f*, is as small as the probable error of observation. But it is the fact that each is the half of the transferable charge that is wanted to prove equal capacity in the two apparatuses. It is very near that result now that the inductive residual effect is taken into account.

4064. Again

i, Air	ii, Air	*First form*
balls as before		
	. . 154°	
	. . 147°	
divided and instantly took		
70° . .		
	. . 78°	
	. . 5°	immediately after discharge.
0° . .		Do.

$\frac{147-5}{2} = 71^\circ$—very close on 70° of i, and not far from $78 - 5 = 73$ of ii.

4065. Again . . . .
balls as before
. . 0°
254 . .
250 . .
divided and instantly took
. . 122
124 . .
1 . . when discharged.
. . 2° when discharged.

$\left.\begin{array}{r} 124 - 1 = 123 \text{ for i} \\ 122 \text{ ,, ii} \end{array}\right\}$ not far from $124{\cdot}5 = \frac{250-1}{2}$; and the latter as it ought to be, a little the highest because of gradual loss. These results shew satisfactorily the equality of power in the two apparatus and the practical correctness of dividing process.

4066. Now proceeded to experiment, using the shell lac hemisphere which was cast on the 6th instant ( ). New shell lac cleaned but not otherwise dissolved and purified.

4067. This was introduced in the first instance into Apparatus i, and then charges divided according to the first form.

i, Shell lac ii, Air
balls 255°
0° . .
. . 304°
. . 297°
divided and instantly took
113° . .
. . 121°
0° . . after being discharged.
. . 7° after being dischgd.

Now $\left.\begin{array}{r} 121^\circ - 7^\circ = 114 \text{ for ii} \\ 113 \text{ for i} \end{array}\right\}$ these are nearly alike, but they are far from 145, the half of $297^\circ - 7^\circ$.

$\left.\begin{array}{r} \text{The Air in App. ii has lost } 176^\circ \\ \text{lac in App. i has gained } 113^\circ \end{array}\right\}$ hence capacities are as $\begin{array}{c} 1 \\ 1{\cdot}54 \end{array}$

4068. I find I can easily discharge the stems by breathing on them and silk wiping, the brass ball R being at the same time uninsulated.

4069. Again

i, Shell lac	ii, Air	
0° . .		
	. . 466°	
	. . 454°	
divided and instantly took		
171 .		
	. . 188	
0 . .		after discharge.
	. . 12	after discharge.

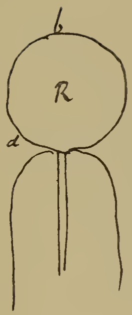
$$\left.\begin{array}{r}\text{Here } 188^\circ - 12^\circ = 176^\circ \text{ for ii}\\ 171^\circ \text{ for i}\end{array}\right\}\text{ these far from 221 or the half of}$$

454° – 12°.

$$\left.\begin{array}{l}\text{The air in App. ii has lost } 278^\circ\\ \quad\text{lac in ,, i has gained } 171^\circ\end{array}\right\}\text{ hence capacities are as }\left\{\begin{array}{l}1\\ 1{\cdot}62\end{array}\right.$$

4070. The ready and perfect discharge of i seems to shew distinctly that the shell lac inside has not taken a permanent Charge.

4071. After i had stood some time from the last experiment without contact, it gave 7°. By touching the ball R, this disappeared at once; then *b* was 0°. On trying the state of *d* when R was uninsulated, obtained only 8°. Hence the assumption of a charge of 7° by i after it had been discharged was probably due to a charge which the shell lac inside had taken on in the beginning of the experiment and which when the metal was discharged returned to it again. This must be considered, as it would give greater apparent capacity—but then unless a real discharge of part took place through the shell lac, the electricity ought to return again to the metal and shew itself in a proportion consistent with apparent difference in specific Dielectric power.



4072. One of three things must be. Shell lac must be a conductor; or else the charge must return in full to the metal; or else it has *greater capacity* for electric induction.

4073. Now transferred the order of charge, i.e. electrified i whilst it had the shell lac within, and then divided the charge with ii *having Air.*

	i, Shell lac	ii, Air
		. . 0°
at 12′	215° . .	
	204° . .	

	i	ii	
time 8′	divided and quickly took		
		118°	
	118°		
		0°	after being discharged.
20′	0°		after being discharged.

$$\left.\begin{array}{l}118^\circ \text{ for i}\\ 118^\circ \text{ for ii}\end{array}\right\}\text{—good way from 102 or } \tfrac{204}{2}.$$

$$\left.\begin{array}{ll}\text{The Air in app. ii has gained} & 118\\ \text{The lac in app. i has lost} & 86\end{array}\right\}\text{ hence capacities are as }\left\{\begin{array}{l}1\\ 1{\cdot}37\end{array}\right.$$

4074. I did not again discharge i or ii, but observed their spontaneous recharge.

at 26′ . . ii was about 2°
27′ . . i „ „ 7°
34′ . . i „ „ 8°

Thus shell lac had given a charge back to the metal as before.

4075. Again . . . .

	i, Shell lac	ii, Air	
		0	
	420°		
	411°		
	divided and quickly took		
		234°	
	240°		
		220°	
	235°		
		1° +	after being discharged.
At 51′	0		after being discharged.

$$\left.\begin{array}{ll}240^\circ & \text{for i or lac}\\ 234 & \text{for ii or air}\end{array}\right\}\text{ far from 205 or } \tfrac{411}{2}.$$

$$\left.\begin{array}{ll}\text{Air in ii has gained} & 234^\circ\\ \text{Lac in i has lost} & 171^\circ\end{array}\right\}\text{ hence capacities are }\begin{array}{l}1\\ 1{\cdot}37\end{array}$$

4076. Having left the app. i and ii at 51′ untouched, examined them again. At 56′, i gave 14°, and this must have been principally due to shell lac inside. At 58′, ii gave 8° of return charge—it had before shewn a residual inductive action of the stem. This is in part the reason why Air was found only 234° instead of 240°—part had been quickly neutralized in the stem.

4077. Now took out the shell lac hemisphere, wiped it well with dry silk and returned it to App. i. I then experimented but found the fall of the charges very sudden. It was dark and I now had to use lights, and these I think discharged the apparatus at a distance—therefore discontinued the experiments.

4078. As the Shell lac hemisphere affects only half the acting inductive surfaces inside the app., it is clear that the effect is much smaller than it would be if the whole of the space were filled with shell lac. Thus, taking the case where the whole induction of the two are as 1 and 1·37, the force of the upper half of each may be represented by 0·5 and 0·5, and therefore the comparison between the lower halves is for air 0·5 and lac 0·87, or 1 : 1·74.

4079. But I am still in doubt as to its being a true effect of difference of capacity for induction. To settle this, I am having a hemisphere of flint glass made and when that is well varnished I think I shall be able to decide.

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4080. To-day proceeded to experiment with hemisphere of shell lac purified by Alcohol and filtration. It appeared by the Gold leaf Electrometer to hold charge well, i.e. to insulate well. Put the shell lac into app. i and first tried retaining power.

4081. i, with alchl. lac — ii, Air

joined at 2′
balls 400°

i, with alchl. lac			ii, Air		
At 2′ above	542°		At 2′ above	542°	
5′ was	523°		7′ was	530°	
10′ „	502°	. . 4·2	12′ „	518°	. . 2·4
15′ „	485°	. . 3·4	17′ „	490°	. . 5·6

Then discharged the app. and instantly after took an observation, and also at further given times.

At 21′ dischd. and instantly took	27°	At 23′ dischd. and instantly .	35°
25′ had risen to . . .	46°	27′ had risen to . . .	42°
29′ dischd. again and instantly took sample, was	27°	31′ dischd. and instantly .	31°
at *d* was	235°	at *d* was	244°

4082. Here observe both seemed at first to lose alike or thereabouts. Then evident that stem charge and action high in both—in *air* app. as well as *lac* app. The return charge is also due in part, and in app. ii probably altogether, to reaction and discharge of stem electricity. So that the shell lac in App. i has not had much to do with the phenomena here. The indications are high as to the action of the stem, because the electrometer repelled ball is charged highly.

4083. Now placed the Alcohol Shell lac hemisphere in the app. ii and proceeded to divide charges.

i, Air	ii, Shell lac Alchl.	
balls as above		
1°·5 . .		
	. . 280°	
	. . 272°	
divided, then quickly took		
157° . .		
	. . 164°	
1°·5 . .		after being discharged
	. . 6°	after being discharged

$$\left.\begin{array}{l}157^\circ - 1^\circ{\cdot}5 = 155^\circ{\cdot}5 \text{ for i, Air}\\ 164 - 6 = 158 \quad \text{for ii, lac}\end{array}\right\} \begin{array}{l}\text{sufficiently near: but differs from}\\ 133 \text{ or } \frac{272-6}{2}.\end{array}$$

$$\left.\begin{array}{l}\text{Air in i has gained } 155{\cdot}5\\ \text{Lac in ii has lost } 108\end{array}\right\}\text{hence capacities are}\left\{\begin{array}{l}1{\cdot}00\\ 1{\cdot}46\end{array}\right.$$

4084. Again . . . .

i, Air	ii, Shell lac Alchl.	
0° . .		
	. . 336°	
	. . 328°	
	. . 318°	
divided, then quickly took		
183° . .		
	. . 197°	
0°·5 . .		after being discharged.
	. . 10°	after being discharged.

$$\left.\begin{array}{l}183^\circ - 0{\cdot}5 = 182{\cdot}5 \text{ for i, Air}\\ 197 - 10 = 187 \quad \text{for ii, lac}\end{array}\right\} \begin{array}{l}\text{some difference, but still [illegible]}\\ \text{far from } 154^\circ \text{ or } \frac{318-10}{2}\end{array}$$

$$\left.\begin{array}{l}\text{Air in i has gained } 182{\cdot}5\\ \text{Lac in ii has lost } 121\end{array}\right\}\text{hence capacities are}\left\{\begin{array}{l}1{\cdot}00\\ 1{\cdot}50\end{array}\right.$$

4085. Perhaps return of charge in ii after the division will account for the height of 197°. Some time elapsed whilst the observation of i was being made.

4086. Now electrified i, *air* instead of ii, *lac*.

i, Air	ii, Lac Alcohol	
balls 360		
	0°	
374°		
370°		
divided, then quickly took		
	146°	
147°		
	0°·25	after discharge—(only 8° at *d*).
0°·5		after discharge—(only 24° at *d*).

The electrometer ball is too highly charged for the indication of such small quantities as 1° or 2°—the effect became attraction altogether at the standard distance of 30°.

147° − 0·5 = 146°·5 for i, Air } but 185° is the half of 370° or
146 − 0·25 = 145·75 „ ii, lac } first charge.

Air in i has lost 223° } hence capacities are { 1·00
Lac in ii has gained 146° } { 1·52

Still therefore shell lac seems to have greater capacity.

4087. Now used the hemisphere of new shell lac, not dissolved—it has the wax in it ( ).

i, Air	ii, New shell lac	
balls 200		
	0°	(only 7° at *d*).
286°		
283°		
divided; then quickly took		
	110°	
109°		
	0°·25	after discharge (17° at *d*)
a little		after discharge (15° at *d*)

109° for i, Air } but 142°·5 is the moiety of divided charge.
110° for ii, Lac }

In this experiment

Air in i has lost 174° } capacities are { 1·00
Lac in ii has gained 110° } { 1·58

4088. Again . . . .

i, Air	ii, New Shell Lac
0°	
	256°
	251°

divided, then quickly took
146° . .
. . 149°
a little . . after discharge (only 3° at *d*).
. . a little after discharge (only 16° at *d*).

146° for i, Air 149° for ii, lac	the half of divided charge is 125°	
Air in i has gained 146° Lac in ii has lost 102	capacities are	1·00 1·43

4089. Find breathing on stem discharges excellently, if at the same time ball R be uninsulated.

Now tried the retaining power of i, Air and ii, New shell lac.

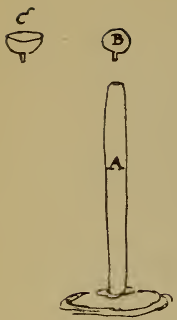
i, Air				balls 390° joined at 57′	ii, New shell lac			
At 57′ above 518°					At 57′ above 518°			
59′	was	510°			61′	was	506°	
			3·6					2·2
4′	,,	492°			6′	,,	495°	
			2·0					2·6
9′	,,	482°			11′	,,	482°	
			2·0					1·7
19′	,,	460°			21′	,,	465°	
			1·86					2·33
49′	,,	404°			51′	,,	395°	
			1·82					2·17
89′	,,	331°			91′	,,	308°	

Hence both retain very well, though the shell lac is in ii. The app. ii always retains best.

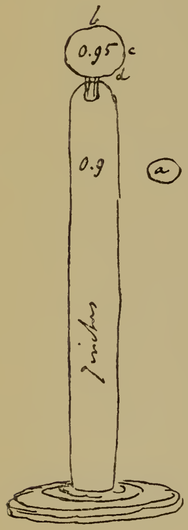
4090. Now tried the retaining power of the Alcohol Shell lac hemisphere: and put it into App. ii in place of the former.

i, Air				balls 400° joined at 39′	ii, Shell lac Alchl.			
At 39′ above 458°					At 39′ above 458			
41	was	455°			43′	was	450	
			1·0					4·6
46	,,	450°			48′	,,	427	
			2·0					5·4
51	,,	440°			53′	,,	400	
			2·2					4·2
61	,,	418°			63′	,,	358	
			2·0					2·9
35	,,	350°			37′	,,	260	

4091. This shell lac therefore loses faster than the other shell lac; and also faster than Air—it conducts or discharges a little. But I think the effect is not enough to account for the difference evident in the inductive experiments. The hemisphere of glass will *settle the matter*.



4092. Now experimented on induction in curved lines. For this purpose I have prepared a stem of shell lac A which, being fixed into a wooden stand or foot, has a little socket formed in it at the top, into which the short brass stem of a brass ball B, or that of a brass hemisphere C, can fit and so the latter be sustained on the former. It is the part of the shell lac at A and above that, being excited, is intended to act on B and C. No lacquer upon the ball or hemisphere.



4093. The dimensions were as follows:

Length of stem 7 inches.
diameter of stem 0·9 of inch.
diameter of ball B 0·95 „
diameter of hemisphere C 1·36 inches.

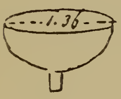
The hemisphere was not quite complete, being rounded at the upper edge*.

Positions and places are marked by the letters *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*, *i*, etc.

4094. Excited the upper part of the shell lac by rubbing it with warm flannel—was *Neg.*—and put ball B into its place. Charged the repelled ball of Electrometer by power taken by the carrier ball from *d*—was *Pos.*

	balls 360° *Pos.*
Charge taken at *b* . .	149°
„ „ *c* . .	265° 276°
„ „ *d* . .	512°
„ „ *a*	above 1000°
„ „ *b* . .	130°

As in former cases, the charges were all *Pos.*, and therefore all inductive effects from lac stem.



4095. When the carrier ball was applied to B, the latter was always thrown into communication with the earth by a wire descending on to *b*. Generally this uninsulating contact was broken first and then the carrier ball removed, but in the case of *c*, it was broken first *before* and then *after* the removal of the trial charge. The difference is so small that it is more likely due to the ball being a little nearer *d* in the latter case than the former. If the breaking of contact and removal of carrier ball are made close together, there should be no sensible difference.

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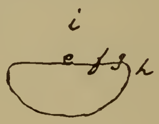
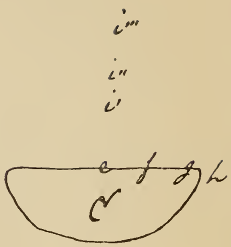
* [4093]



4096. Now the hemisphere C was put in place of the ball B.

e	58°	*i′*	87° about $\frac{1}{3}$ of inch above surface.
f	65°	*e*	35°
g	108°	*i″*	105 taken higher than *i*.
h	112°	*i‴*	98 taken higher still than *i″*.

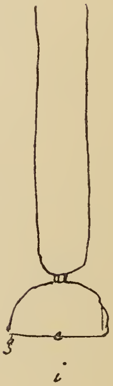


4097. When the carrier ball was at *i*, *i″* or *i‴*, then C was first uninsulated—next carrier ball uninsulated, insulated and finally removed for examination.

4098. The carrier ball is of an inch in diameter.

4099. If an uninsulated conductor is held at a little distance round the shell lac stem, so as to act by induction, it ought to remove part of the inducing force from the ball or hemisphere above: so that if the latter be then touched; insulated, and the conductor round the stem withdrawn; the return of the induction on to the hemisphere ought to bring the upper part into a contrary state to that it has when connected with the earth. This was found to be the case, for under such circumstances *e* was *negative*. But on uninsulating C, *e* at once acquired a *Pos.* state. This clearly shews that all the effects are effects of induction, and not of communication, and establishes the fact that induction acts in curved lines.

4100. Now inverted the shell lac stem and its attached hemisphere, to cut off effects of current, etc., though their absence is fully ensured otherwise, but the results were the same.

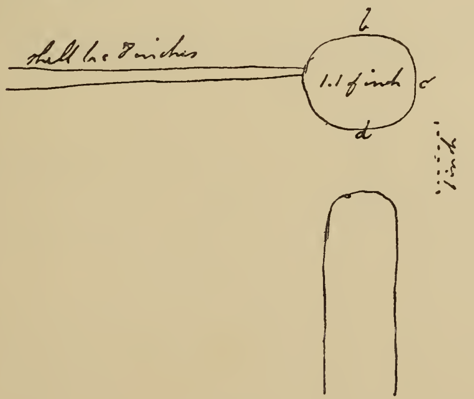


At *i*	158° (1 inch off)	All *Pos.*
c	46	
g	148	
i	88 (about inch off)	
i	94 (a little nearer)	

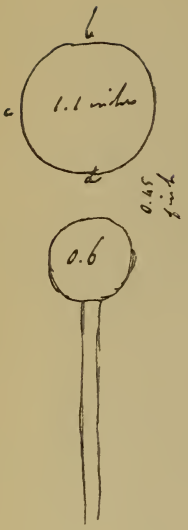
4101*. Supported a ball 1·1 inches in diameter on a shell lac stem quite clear of excited shell lac and about 1 inch distant from it. Then examined state and force at *b*, *c* and *d*.

At *b*	22°	all *Pos.*
c	97°	
d	195°	

* [4101]



4102. These perfectly consistent with the former results where ball was in contact with the excited lac.



4103. Now used the ball of a charged Leyden jar as the inducting agent, supporting the ball of 1·1 inches above it at distance of 0·45 of inch. The Leyden jar ball was only 0·6 of inch in diameter.

4104. As Leyden jar was charged *Pos.*, the inductive ball was found on all parts *Neg.*, and the Electrometer balls were charged *Neg.* to 360°.

At *b* . .	47°
c . .	147°
d . .	460°

The results perfectly in accordance with the rest.

4105*. Here the point must discharge and become luminous—but only in virtue of induction in curved lines—though when it discharges, the effect of current and repulsion of similar currents comes in.

4106. Fusinieri think[s] that easy diffusn. in vacuo is due to removal of the *obstacle* of the air to expansion of matters from which electricity emanates. Bib. Univ., 1831, xlviii, 375—but shall explain this otherwise on the molecular theory.

4107. My view shews reason why rarefaction causes ready discharge.

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4108. Have had a Flint glass hemisphere made and well varnished with Alcoholic solution of shell lac, and also well dried. It is not quite so good a fit as the shell lac but its average thickness is of an inch, leaving not more than of an inch of air for the induction to act through. Put it into App. ii—after it had recently been well warmed and whilst it was warm.

4109. Allways charge the app. now by a little Leyden Jar as before described ( ).

4110. Observed this morng. on preparing to experiment that there was a fine velvet or dimness upon the surfaces of shell lac stem and ball above, due to dust attracted by them. It illustrate[s] the way in which the stem becomes charged.

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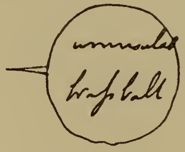
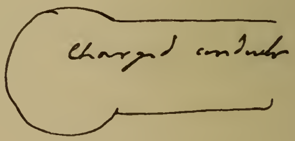
* [4105]





4111. i, Air ii, Flint glass, thick and varnished
balls 330°
0 . . . . 17° at *d*.
. . 408
. . 394
divided, then quickly took
210° . .
. . 222°
32° at *d* + . . } after discharge.
. . 18° . . . . . . 187° at *d*.
210° . . . for i, air } 188°, is the half of divided charge = $\frac{394 - 18}{2}$
204° or 222 − 18—ii, Glass }
Air in i has gained—210 } capacities are as { 1·00
Glass in ii has lost —172 } { 1·22

4112. Again . . . .
+ . . . . 26° at *d*.
. . 337
. . 320
. . 319
divided and quickly took
175° . .
. . 175°
168° . .
(13° at *d*) + ... } after discharge.
. . 1·5 . . (40° at *d*) }
i, Air = 175 } 155·7 is the half of divided charge = $\frac{313 - 1\cdot5}{2}$
ii, Glass = 175 − 1·5 = 173·5 }
Air in i has gained . . 175 } capacities are { 1·00
Glass in ii has lost . . 138 } { 1·26

4113. . . . . 20° at *d*.
290° . .
285° . .
divided, and quickly took
. . 118°
115° . .
. . 0·5 . . (17° at *d*) } after discharge.
0° . . . . (0° at *d*) }
i, Air . . 115° } 142·5 is the half of the divided charge.
ii, Glass . . 117·5 }
Air in i has lost . . . . 170° } capacities are { 1
Glass in ii has gained . . 118 } { 1·44

4114. Again . . . .

i, Air	ii, Flint Glass varnished (thick)
	. . 0° . . . 2° at *d*, after breathing on stem and not wiping it.
278° . .	
272° . .	
divided, then quickly took	
	. . 110°
111° . .	
	. . 0° . . . 4° at *d* } after discharge.
0° . .	. . . . 0° at *d* } after discharge.

i, Air . . . 111° }
ii, Glass . . 110° } 136 is the half of the divided charge.

Air in i has lost . −161 } capacities are as { 1·00
Glass in ii has gained—110 } capacities are as { 1·45

4115. Now tried the retaining power of the two apparatus as left from the experiments.

balls 500
joined at 45′

i, Air		ii, Thick flint glass	
At 45′ above 670		At 45′ above 670	
46′ was 665		48′ was 616	
51′ „ 634	. . 6·2	53′ „ 531	. . 17·0
56′ „ 625	. . 1·8	58′ „ 463	. . 13·6

Thus glass in ii loses much too fast—took it out to warm well and in the mean time tried the app. with air in both.

4116.

balls 460°
joined at 20′

i, Air		ii, Air	
At 20′ above 630°		At 20′ above 630	
21′ was 623°		23 was 630	
26′ „ 608°	. . 3·0	28 „ 613	. . 3·4
31′ „ 595°	. . 2·6	33 „ 600	. . 2·6
41′ „ 570°	. . 2·5	43 „ 585	. . 1·5
51′ „ 555°	. . 1·5	53 „ 560	. . 2·5
71′ „ 497°	. . 2·9	73 „ 520	. . 2·0

Thus ii (and i also) holds very well at these charges without the glass inside—shall see what it will do when well warmed and dried.

4117. The well warmed glass experimented with—first as to its retaining power.

joined at 22′

i, Air		ii, Thick flint glass	
At 22′ above		At 22′ above	
23′ was 460°		25′ was 475	
28′ „ 455°	. . 1·0	30′ „ 458	. . 3·4
33′ „ 447°	. . 1·6	35′ „ 442	. . 3·2
43′ „ 425°	. . 2·2	45′ „ 417	. . 2·5
53′ „ 410°	. . 1·5	55′ „ 403	. . 1·4

4118. Thus here app. ii with warm glass holds vastly better. Now what is the capacity? Warmed it first for 2 hours more and then experimented as follows—

4119. i, Air balls 280° ii, Thick flint glass warmed
. . 2° . . (18° at *d*)
533° . .
517° . .
517° . .
divided: then quickly took
. . 220°
227° . .
. . 214°
. . 3° . (27° at *d*) } after discharge.
(85° at *d*) . . 12° . . . . }

i, Air = 227 − 12 = 215 }
ii, Glass 220 − 3 = 217 } 252·5 is the half charge = $\frac{517-12}{2}$

Air in i has lost . . . . 290 }
Glass in ii has gained . . 217 } capacities are as { 1·000 / 1·336

4120. Again—with Glass charged . . . .
0° . .
. . 393°
. . 393°
divided, then quickly took
229° . .
. . 235°
2° . . . . . 6° } after discharge.

Now here
i, Air = 229 − 2 = 227° }
ii, Glass = 235 − 6 = 229° } 193·5 is the half charge = $\frac{393-6}{2}$

Air in i has gained . . 229° }
Glass in ii has lost . . 158° } capacities are as { 1·00 / 1·45

4121. Now again tried the retentive power after these two results.

i, Air		ii, the thick glass	
	joined at 15′½		
At 15′½ above 340		At 15½ above 340	
16′ was 326		18′ was 337°	
	1·2		3·4
21′ ,, 320		23′ ,, 320°	
	2·6		0·0
26′ ,, 307		28′ ,, 320°	
	0·7		2·0
36′ ,, 300		38′ ,, 300°	
	2·1		1·6
46′ ,, 279		48′ ,, 284°	
	1·2		1·7
56′ ,, 267		58′ ,, 267°	

Thus the results good—for the whole fall is not much and is alike in both—the irregularities must be errors of observation.

Then discharged both and found i gave 3° and ii 5° at *b*.

4122. Taking the app. as left yesterday, all closed up, now tried them as to capacity to see how they remained.

i, Air balls 280° ii, thick glass
. . 0° . . (0° at *d*)
415° . .
400° . .
divided, then quickly took
. . 164°
160 . .
. . 157° not much dropping.
. . 0° . . (3° at *d*) } after
0 . . . . } discharge.
i, Air . . 160° }
ii, Glass . 164° } 200° is the half charge.
Air in i has lost . . . 240 }
Glass in ii has gained . . 164 } capacities are as { 1 / 1·46

4123. Again:

i, Air ii, Thick Glass
. . 0°
326° . .
318° . .
divided, then quickly took
. . 129°
129° . .
. . 127° not much fallen.
. . 0° . . (2° at *d*) } after
(5° at *d*) 0° . . . . } discharge.
i, Air . . . 129° }
ii, Glass . . 129° } 159° is the half of the original charge.
Air in i has lost . 189° }
Glass in ii has gained 129° } hence capacities are as { 1·00 / 1·46

4124. The glass evidently, upon the division, takes up its charges state *at once*: there is no delay. Again, there is but little fall after. This throws out of view the difference of capacity as an effect of induction. Especially as when the glass is charged first it, upon division, gives up *at once* the half of the divided charge, or at least its proper portion.

4125. The cause of the inaction of the stem this morning is the absence of dust, because of the quiet state of the room. It is early morning hours, and nobody in the rooms but myself as yet.

4126. Again—charging the glass first . . . .

0° . .
. . 306°
. . 297°
divided, then quickly took
170° . .
. . 170°
After discharge } 0° . .
(a little at *d*) }
. . 163°
. . + . . (4° at *d*) after discharge.

Here the $\left.\begin{array}{r}\text{i, Air} = 170^\circ\\ \text{ii, Glass} = 170^\circ\end{array}\right\}$ 148°·5 is the half of divided charge.

$\left.\begin{array}{ll}\text{Air in i has gained} \;\;.\;\;. & 170^\circ\\ \text{Glass in ii has lost} \;\;.\;\;. & 127^\circ\end{array}\right\}$ hence capacities are $\left\{\begin{array}{l}1\\ 1{\cdot}34\end{array}\right.$

4127. The app. i and ii are now in good condition as to the state of the stem and room. Now therefore charge one of them, namely ii, with glass—let it remain a little while—then discharge and take an observation instantly after (which should include no effect from the stem if that be clear and good), and also again at further intervals of time, to see if any charge comes on of itself.

ii, with thick glass in it
balls 145
382°
365°
354°
354°
344°—then discharged and made instant
contact with carrier ball— 0°
in a short time was 12°
a little while after 13°—then discharged and again
reduced the effect to 0°—and it did not rise again.

After all this trial, being tested at *d*, there was scarcely any thing. Hence the result as to the coming on of a charge very striking and good, *but very remarkable.*

4128. Now took out the glass and put it to warm; and in the mean time repeated the same experiment with ii, Air only being in it. Except that the stem is shell lac and that the part in the socket and within the ball may and will have its proper action like that of the glass just now. The result was as follows:

ii, with Air
302°
278°
265° . . carrier in contact—discharged
and instantly removed the ball . . 15° . . this high and perhaps accidental
discharged the carrier therefore
first; still 22
Again . . . . . 22 having first discharged the carrier.
Now made another discharge contact with ball R and now it was 0° and removed 0° (At *d* only 5°).

4129. Thus ii with Air fell as fast after first charging as it did with glass. It also had a residual charge. But I must repeat the experiment and reduce it by discharge to 0° before I begin to observe the consequent recharge.

4130. Perhaps the loss of power at first charge was due to the dirty state of the outside shell lac. Wiped it therefore, with silk (linen is bad for it quickly electrifies shell lac). Then

at *d* . . . . 45°
„ *b* in R . . 4°
Charged . . . . . . 228°
209°
203°
198° . . put carrier on to R
at *b* and discharged quickly and then . . 6°
in a minute or two rose to . . . . . 12° . . discharged both again
at once as before—then fell to . . . 4° or the first quantity and did not change.

4131. Again with Air in ii, having previously wiped the inside of the app. well—and it now seemed to hold charge better than before, as if some dust had been inside: thus—

being charged it was at . . . . . 830°
828° } this excellent retention
805°
805° now put carrier ball on R and
discharged by a tap of wire . . . . 130°. Now this tap had been good and hard, but the discharge could not have been perfect—tried again for security . . . . 144°, so it had not been discharged, but still it had risen after the partial discharge. Again discharged,
was . . . . 12°
in a few moments rose to . . . . . 17°—then a prolonged discharge
of carrier and R together—was then . . 7°½, and this remained, being the effect of the stem acting inductively (124° at *d*).

4132. Thus it takes time to discharge, even when air inside—(perchance stem has an influence). Still can observe the case of the return charge notwithstanding.

4133. The thick glass being very well warmed, was put into App. ii and the apparatus charged for 10′, being then discharged.

It gave . . . . 16°
17° being then charged again and tried
at four times was . . . . . 629°
620°
603°
592° being then discharged
it gave at first . . . . . . 12°
then rose to . . . . 32° being again discharged
it was at 13
14 } the carrier ball being discharged each time.
15

Thus there seems to be some return charge from the glass.

4134. Now tried the best alcohol shell lac in the same way. It was made warm and put into app. ii, and being examnd., was found to give 11° at *b* by inductive action.

Being charged it was	337°	loss very quick, 144
	267°	
	205°	
	193°	
charged up again	427°	—loss not so quick: in the last four only 85
	365°	
	315°	
	287°	
	280°	
charged up again	404°	94 loss from 404°
	363°	
	334°	
	310°	
again charged	424°	loss is the slowest here; 78 from 424° in four trials.
	390°	
	364°	
	346°	
	326°	Now put carrier and R
into contact—discharged fairly—separated, etc.	11°	
tried again immediately (i.e. 1½ minutes) . .	58°	—a striking rise
	69°	—still rising
	79°	
	83°	
	87°	
	90°	
	92°	—still rising
	92°	—even now it must be evolving electy. to counterbalance the constant dissipation going on: discharged again slowly and well and then found it at . 11° or the first number, being the inductive effect of the stem. Hence a charge of 81° had in this way returned from an unperceivable state.

4135. It is clear also that tension is lost in giving a charge and that it returns again afterwards when discharge is made. Perhaps conduction enough here to make a difference. It seems to take time to give the new electro tonic state and also time to undo it, but the return from 11° to 58° was quick. The first loss may therefore be quick and it will be seen that the rate of loss or disappearance was very much quicker in first charge than at the fourth charge.

4136. Continued to work with App. ii and the alcohol shell lac No. 3 remaining in it. Charged it and left it 10′, then recharged it two or three times, until perhaps 20′ had elapsed. Was then discharged and the *stem cleared* of all electricity by breathing and wiping, whilst R ball was uninsulated. In this way discharge quite perfect;

then at *b*	1°	37°
	10°	37°
	21°	40°
	23°	42°
	31°	43°—then discharged carrier and R
and found the app.		0°; even at *d* it was only 9°.

Hence a clear proof of return of charge from the Alcohol shell lac No. 3.

4137. This effect seemed to occur also with air: if it does, and thus gives a condition of exclusive induction in the line connecting the two surfaces, which is not accompanied by any action in the opposite direction, it will have an important influence in the discharge of surfaces by *currents* as by *air*, *oil turp.* and also in respect to the action of points, edges, etc. etc., and perhaps even form generally.

4138. Taking the whole action as induction, then it is clear that glass or shell lac in that state cannot have such capacity for induction as that not in the state. Whether call the whole induction, or divide the phenomena, as they ought to be, still it stands in favour of an action of particles.

4139. Then experimented in the same exact manner with the Glass in No. ii, it having been well warmed previously. After being charged several times and then discharged and the stem cleared, it gave:

at *b* . . . . 0 or rather even a little attraction.
+ or nearer to repel ball—a little attrctn.
1½
2½
3½
5
5½
6
6½
6½
7

These, like the other observations, were as quick as they could be conveniently taken, and occupied about 1′ or 1′¼ each

in 5′ or 8′ more was . . 8. Then all being discharged, the effect at *b*
was . . . . 2½, or at *d* was 40°.

4140. Thus glass produces the effect and state, but apparently not in the degree that shell lac does.

4141. The assumption of a charged state in the stem, it being 0° at first, is probably of the same kind of action. It would bring the outside ultimately into a negative state.

4142. *Shell lac.* Now experimented with the second melted shell lac No. 4—after making it warm and in good condition, and putting it into No. ii. I cleared the stem of No. ii but forgot to take its state. After about 10′ electrification, it was discharged and the stem cleared:

balls were at 270
at 21′ . . 0—or rather attraction.
12
19
24
25
30
32
33
at 31′ 35
36
„ 35′ . . . . 36—then discharged all and
foun[d] *b* was . . 0 or 9° at *d*.

4143. The shell lac therefore takes up this peculiar condition and to a greater extent than glass. It therefore is not so good as glass in deciding the question of specific inductive capacity.

4144. Now divided a charge with same shell lac.

	i, Air	ii, Shell lac (cast) No. 4
		. . 0 or rather attraction
	197° . .	
	198° . .	
	divided, then quickly took	
		. . 78°
	80° . .	
		. . attraction as at first (or 5° at *d*)
(60° at *d*) . .	3° . .	

ii by standing did not acquire *any* electricity after the discharge.

$$\left.\begin{array}{ll}\text{i, Air } 80-3 \;.\;.\; = & 77\\ \text{ii, Shell lac} \;.\;. & 78\end{array}\right\} 97\cdot5 \text{ the half of divided charge } \frac{198-3}{2}$$

$$\left.\begin{array}{ll}\text{Air in i has lost} \;.\;.\;. & 118\\ \text{Lac in ii has gained} \;.\;. & 78\end{array}\right\} \text{capacities are } \left\{\begin{array}{l}1\\ 1\cdot51\end{array}\right.$$

4145. Remember this shell lac thicker than the Alcohol one—hence better.

4146. Though glass a better substance than shell lac, still I think the last experiment is a good one and depends on a difference of capacity. The shell lac was tested *immediately after* being charged, and not being suffered to remain charged long, neither the *stem* nor the *hemisphere* had taken up any extra state.

4147. To see what effect excited shell lac would have in the hemisphere, if charged by accident and not in the peculiar state, I first excited the hemisphere strongly with flannel; then put into App. ii—then discharged ii—then tried it at *b* by the carrier ball and found 0°. Of course this ought to be so, as all the actions are in the lower part.

4148. Are the side[s] of the glass and lac charged with the *same* electricity as the metal contiguous? If so, it may be surface conduction, and not action of the mass within. Then the induction in such cases might be compared with that of air by diminishing the interval until it is equal to the whole thickness of the shell lac—as by using the metal lining.

4149. Consider the relation of *distance* in the new theory of induction by particles—and how the known effects of distance affirm or negative the theory.

4150. There are many experiments which seem to shew that conduction or discharge is favoured at the surface of bodies in contact, either of which alone would not conduct or discharge so well as the two. Now the conduction at surfaces may be connected with the difference of capacity or tension of the particles of different bodies—the theory and the effects may illustrate each other.

4151. The kind of conduction over surface referred to is evident in charging a resinous plate by a jar—the electricity darts and expands over the plate.

4152. It may be connected with the discharge over surfaces, even when as a spark, as over paper, glass, string—even gold leaf, etc. etc.

4153. May be connected also with collection from charged glass by knuckles, knobs, etc. etc.

4154. By my theory, Harris' wonderful foreknowledge of electricity in making out its easiest passage very easily explicable (3592).

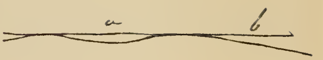
4155. Perhaps the differences between Harris and Poisson may now come out and be explained.

4156. *Time* an element in conduction shewn by the half discharge of a large battery by fine silver wire.

4157. Must consider what conduction, induction, intensity, actions of points, discharge, brushes, spark, etc. etc. etc. are under new theory.

4158. Where is Whewell's account of Poisson's theory?

4159. With respect to conduction over surface of electric, it does not seem to take place if the air varies in thickness in opposite directions: thus in Electrophorus apparently will not take place in such a spot as *a*, but will at one like *b*. Remember here the effect when stem of app. i was open in the socket.



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4160. Put the last cast shell lac No. 4 into app. ii—charged it for 10′ rather highly—then discharged the apparatus—took out the shell lac and examined it by holding its surfaces towards the cap of a gold leaf electrometer (not very delicate). Could perceive no traces of electricity either on the convex or concave side.

4161. Replaced the shell lac in the app.; recharged it again for 15′, then discharged the apparatus and its stem perfectly.

at 35′	0°	very little even at *d*.
37′	13°	
40′	17°	
47′	26°	

So that the result is as before and very decided.

4162. Now recharged the apparatus at 50′ up to 720° or above.

at 50′	above 720°
55′	730° so holds well.
65′	695°—this being after a recharge from Phial.
95′	630—so holds well.

After this 45′ of charge, discharged the apparatus and stem, and then the carrier ball at *b* shewed little attraction on the electrometer repelled ball, so that *all charge* was removed. The apparatus was then opened and the shell lac taken out and placed upon the table to have its surfaces examined. This was done by bringing the carrier ball near, uninsulating it, insulating it, and then removing it; so that it always had the contrary state to the examined surface.

4163. The ball, charged by induction thus, opposite the outside or convex surface of shell lac, repelled the Pos. ball in electrometer, but when charged opposite the concave side of shell lac, it attracted the Pos. ball, and the attractions and repulsions, feeble at first, became stronger at each successive trial. Hence the convex surface became more and more *Neg.* and the concave or inner surface more and more Positive. And as these were the states of the metallic surfaces against the shell lac, it is clear that Pos. electricity has left the Pos. metal and gone into the shell lac, to be hidden for a time, and return after the propelling tension of that metal surface was taken off by the discharge.

4164. Examined the ball R of the apparatus, after the shell lac had been taken out some time, and found it slightly positive. It had been neutral; and this positive condition is a result of return action from the shell lac stem of the same nature as that which had been examined in the hemisphere of lac.

4165. This kind of action supplies another mode by which the shell lac stem may become charged, besides that by contact and that by flying dust.

4166. The effect of the surfaces of the shell lac hemisphere became more and more powerful for some time. The state cannot be a mere charge of the surface, for that would be as strong at first as afterwards, but it is a charged or polarized state of the mass of the electric, driven in or caused by the force of the excited conducting surfaces, and returning altogether or in part (as remains to be ascertained) to its first state, when the impelling or inducing condition of the charged surfaces is taken off. Hence the *gradual* resumption of the external or charged state from a previous state of indifference. The remarkable point is, that during the state, the opposite forces, though not in their natural combined association (as is proved by their spontaneous after separation), should still perfectly neutralize each other for the time. In ordinary cases of induction, i.e. supposing the two sides (to any depth) to be in opposite states, still, though they would induce towards each other, they would also induce to bodies external to them also—as in a charged Leyden plate.

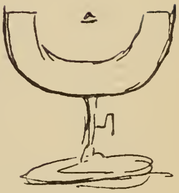
4167. I must however make a plate of shell lac with mixed particles of conducting matter in it, and see what they will do.

4168. The prevention of this effect with effects of capacity will be best obviated by choosing the solid insulator shewing least of this power (as glass perhaps) and also experimenting quickly.

4169. Is not this condition the *first step* in the process of conduction—and is not the case itself a case of conduction of the slowest kind, and therefore very instructive and explicatory?

4170. Is it possible to cause this state without induction? I anticipate *not*. If it can be, it will be very important. Must try whether a stick of shell lac, being excited for some time and then discharged, will afterwards resume an excited state—for that would be the case in point. That would be equivalent to an absolute charge of matter with one electricity.

4171. Replaced the shell lac in the App. ii, and electrified the app. Pos. After 15′ removed the upper half of the apparatus with its balls, etc., leaving the shell lac in the lower hemisphere, quite uninsulated. Then put carrier ball at *a*, touched it, insulated it, removed it and found it at first repulsive of electrometer ball, being in a *Pos.* state. Continuing to repeat the trials, this state gradually diminished, and after the third trial was neutral, and then the ball became attractive or negative, which state gradually increased in strength for half an hour or more.

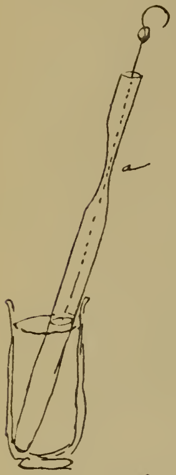


4172. Thus the surface of the shell lac was at first *Neg.* and then of itself became *Positive*, and this a very striking state and condition. It shews clearly that the after reaction is due to the state of the internal parts of the shell lac and not of the external only.

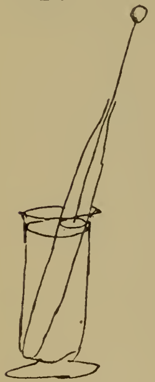
4173. The first neg. state of the surface corresponds to what it should have, as opposed to the Pos. state of the metal ball previously opposed to it. This Neg. electricity is probably the consequence of the P. influence having been turned by the predominating power of the charged ball in the opposite direction and so leaving the particles Neg. I mean it is not at all evident as yet that the Neg. Electricity has passed as a current from the opposite side. It is just as likely as yet that it was developed (by a kind of polarization of the particles) where it was found.

4174. The above state of things shews that a comparison of this apparatus in such a state cannot properly be made with the other one having the metal lining inside to lessen the interval of air.

4175. The slow return of the masked electricity is against the notion that when the app. with *shell lac* is used to divide the charge of that with air by a momentary contact, the difference of Specific capacity can depend on this returning electricity—for the Air app. could not in that moment procure it and yet it is charged far above the mean. This is perhaps *the best argument* for a difference in capacity in different bodies.



4176. Made arrangements to ascertain whether the conducting power of glass was such as to be very sensible in some weeks, and cause perfect and final recombinations of electricity through it. Some tubes of glass (flint) of inch in external diameter and of inch in thickness were hermetically sealed at one end and drawn out near the top: from 2 to 3 inches in depth of clean mercury was poured into each by a tube funnel: then a wire with a loop at the top was dropped into the tube; the lower part of the tube placed in a cup of uninsulated mercury, so as to form a little Leyden jar of the tube and its contents; and the wire was then withdrawn by the knob and wire of a *charged* Leyden jar. The glass at *a* was immediately sealed up hermetically, and though a little discharge took place at the moment of applying heat at *a*, still the lower part was left in a charged state. There were five of these tubes prepared and all were charged *Positive* inside.



4177. In about half an hour, opened one to see if it was fairly charged. Broke off the top; by means of a shell lac hook dropped in a wire with a gilt pith ball at the top. Then applied carrier ball to it and found it acquired a fair charge though not a high one (some of the electricity having been dissipated at the moment of sealing the tube). When discharged by a bent wire it gave also a fair spark.

4178. The other four were then set aside carefully for examination hereafter. See 14 June 1839 (5090).

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4179. This morning tried one of the little charged tubes ( ). When the Electrometer balls repelled with a force of 600°, it gave a charge of above 500°. When coated outside with mercury and discharged by a wire, it gave a good little spark.

4180. Put the rest bye in a glass, resting satisfied that in its common state glass conducts quite well enough to keep the outsides in an uninsulated state. Put one of them into uninsulated mercury to make the discharge of outside quite unexceptionable.

4181. Experimented on divided charges. Placed in App. i the metal lining (   ), so as to diminish the thickness of air in that part to   of an inch. Placed in App. ii the best fuzed shell lac hemisphere No. 4 (not Alcoholic).

i, Air (contracted)   ii, Shell lac
0° . .   even at *d*.
. . 444°
. . 438°
divided, then quickly took
255° . .
. . 262°
Attrn. . .
. . Attrn. } after discharge.

The attraction is the effect of the charged Electrometer ball on the uncharged carrier. Perhaps App. ii ought to be taken first after the division, to avoid the effect of the return charge to it after the partial discharge by dividing. Now here the results are:

i, Air (narrowed) = 255
ii, Lac . . . . = 262 } 219 is the half of divided charge = $\frac{438}{2}$
Air in i has gained 255
Lac in ii has lost 176 } capacities are as { 1·00
1·45

Hence the superior power of shell lac, even though in the air app. the metal surfaces are nearer.

4182. Again—charging the Air.

i, Air (narrowed)   ii, Shell Lac
. .   0° or attraction even at *d*.
383° . .
373° . .
divided, then quickly took
. . 152°
152° . .
. . 148°
. . Attrn.
Attrn. . .   . . . } after discharge
i, Air (narrowed) 152
ii, Shell Lac . . 152 } 186·5 the half of divided charge = $\frac{373}{2}$
Air in i has lost —221
Lac in ii has gained—152 } hence capacities are { 1·00
1·45

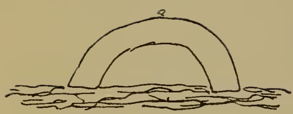
or exactly the same as when the shell lac was charged first and that charge divided.

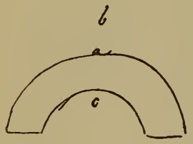
4183. It is very beautiful to observe how little charge of the stem outside there is, when there is no dust about. The morning is damp, I am alone, and *all is quiet* in the rooms.

4184. From the above and the other results, I cannot resist the impression that there IS *a difference of inductive capacity in body*. I do not see how it can be explained away, though I try all I can for that purpose.

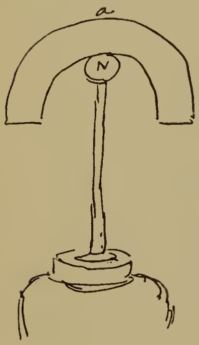
4185. Put i and ii away, without glass or shell lac inside, but empty.

4186. When one surface only of shell lac is excited, it ought to act by induction through the shell lac in one direction just as well and to the same degree as through the air in the opposite direction, or even to a greater degree, because of superior capacity of the lac. There should be nothing like *selection* or preference as to the *direction* of the force. Nothing like an axis of action.





4187. To try this generally, the Shell lac No. 4 was cleared over both surfaces by breathing and wiping with silk (and fingers), then laying it on folded dry silk; it was excited at *a* by friction with flannel and rendered *Neg.* there. Next the carrier ball was placed at *b*–uninsulated, insulated, removed and examined by the electrometer–it brought away *Pos. electy.* Then applying it in the place *c* and repeating the process necessary for induction, it acquired *Pos. electy.* there also; stronger than before, probably however because of concave form there of acting surface. Then discharged the surface *a* by breathing and wiping, taking care all the time not to touch the inner or concave surface, and afterwards found scarcely a trace at *c*, and even that accompanied by a little at *b*, as if a small residual action. These latter effects probably due to a small return action, which was very possible considering the whole time employed. But it appears that *a* remained the excited surface; that the surface inside did not acquire permanent charge; and that induction took place in both directions, i.e. both through air one way and shell lac the other way.



4188. Induction through shell lac and air roughly thus. A little Leyden jar was employed and the carrier ball charged by induction at *a*, a little distance above the ball N. Whether the shell lac was there as represented or away, the carrier took the same kind of charge, and with no very sensible difference of degree, when examined only in this rough manner. The shell lac came away uncharged in short experiments.

4189. Does not glass, shell lac, etc. etc. take and give up the charge due to ordinary inductive action instantly? All the effects appear to shew that—and in that respect the specific capacity argument stands well.

4190. There appears to be no distance at which induction ceases.

4191. Can attraction be inversely as the square of the distance in cases where the inductive action is in curved lines?

4192. Force of attraction ought to be increased between two surfaces when shell lac is interposed there instead of air. Try this with Harris' balance.

4193. There can be no such thing as free electricity. At least it would appear not. As there can be no such thing as attraction of Gravitation without matter.

4194. May inductive action be transmitted by other particles than those of ponderable matter, as by the particles of the supposed ether? Rare and dense makes no great difference, indeed none when up to gaseous state or above: as far as I have gone yet in the experiments.

4195. According to the theory, *induction* or *conduction* could not take place through *a perfect vacuum*. Morgan says a vacuum does not conduct. In Davy's Experiments, the transmission might be over the surface of the glass, very naturally.

4196. What would successive alternations of different insulators do? Suppose Mica a perfect insulator, then would a thick plate of mica in a certain interval of air do neither more nor less upon the transmission of induction, than the same plate divided into 20 laminæ in the same interval? Could divide the Mica by heating it white hot.

4197. If any sensible action could be traced to the plane at which the induction passed from one substance to another, it would be important.

4198. *Flame*: its discharge of inductive surfaces is probably due to its breaking the barrier of regularity, in the gaseous medium of which it consists, around the conducting and also inducting wick, etc. etc. Hence the effect, and it is very natural that it should be great, for it affects the condition of the inducting medium to a *considerable distance.*

4199. It is possible that the *local electrical effect* in a flame, due to chemical action, may coalesce in part and co-relate with the *distant effect*, when a flame is made to play discharger to an inductive action. In that case, may perhaps find a relation between the *nature* of the flame and its *discharging power.*

4200. The well known phenomenon of return or *residual charge* in a discharged jar or battery—is almost altogether due to *the peculiar masked inductive state* I have discovered, and is well explained by it.

4201. That *peculiar state* will probably connect and associate *induction* and *conduction.* See this by considering the case of a very slow conductor, as Spermaceti, shell lac, etc. etc.

4202. The induction particle theory will, I think, explain the following phenomena.

More easy discharge in rare than in dense air.
Insulation and conduction.
Induction.
Action of points, edges, etc.
Ever occurring equality of Pos. and Neg.
Unity and undivided condition of the current.
Residence of Electricity on the surface of conductors.
Why different conductors hold the same quantity on surface.
Chemical excitation.
Chemical decomposition.
Discharge by flame.
Discharge as a brush—as a spark.
Conducting power given by acids and salts, etc. in solution.

4203. Perhaps also

Common excitation by friction.
„ „ change of form and state.
Thermo-electricity.
Induction of currents of Electricity—this peculiar.

4204. With relation to the effect of acids, salts, etc. dissolved in water, they may act by affecting the relation of the particles of the water and its elements one to another.

4205. In discharge of stem (when charged by dust), breathing and finger wiping is most excellent. Cover the forefinger with one thickness of a clean silk handkerchief—touch the brass ball R constantly, breath on the stem first on one side and then the other, passing the covered finger over the place so as to wipe off the breath, but without changing the part of the silk *which wipes*. In this way the finger in the damp silk discharges, the stem is left clean and dry and above all things, unexcited.

4206. In Electrolyzation, of water for instance, the particles of water as wholes polarize, and then the elements separate and rejoin to others, keeping their polarity, or something like it. Does this lead to admission of a mobile condition of the powers associated with these particles?

4207. Chemical excitation is probably the simplest or at least the most distinct mode of excitation in principle which we possess.

4208. Current electricity has for its lateral or transverse action magnetism or attraction of similar currents. Quiescent or Statical electricity has for its lateral or transverse action the transverse repulsion or state of tension; for the effect is equivalent to a repulsion amongst the lines of inductive force.

4209. As direct tension, which is attraction, causes currents, so the lateral or transverse tension, which is repulsive, causes Magnetism; Ampère's attraction of currents; my electrotonic state, etc. etc. It probably constitutes the electrotonic state.

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4210. Consider as results of this prior condition of the inductive forces the divergence of brushes and the concentration in sparks. Each brush by its individual ramifications shews the convergence of power to an axis of discharge the moment the current begins, and by the separation of the various ramifications, the previous mutual repulsion of the lines of force. I think these considerations relative to the discharge in air, etc. will turn out good.

4211. Consider the incoercibility of the electric power or fluid, either of one or of two, i.e. the impossibility of exhausting its power, or diminishing it in the slightest degree.

4212. It appears as if the Electric forces were very often evolved. Even in chemical actions they are evolved in many cases, i.e. they are not ready in their active state before hand. Hence in many cases the necessary application of a certain temperature, which evolves them under the circumstances, as in the combination of oxygen and hydrogen. May not this be a simple connecting link between chemical action, etc., and thermo electricity?

4213. That which appears to be definite about the particles of matter is probably their power of assuming a *particular* state and to a *certain* amount.

4214. May not excitement of Electricity by friction be in part a thermo-excitement? When two pieces of the same substance are rubbed together, the one more, the other less, may not the two states acquired be altogether results of thermo-electricity evolved on *non-conductors*?

4215. The lateral attraction of similar currents in Magnetism is a force of very small amount as a corpuscular force. Compare it with chemical action. Think of a bar magnetised and not—how little effect is produced compared with that of 10° or a little heat, either added or subtracted.

4216. Compare corpuscular forces in their amount, i.e. the forces of Electricity, Gravity, chemical affinity, cohesion, etc. and give if I can expressions of their equivalents in some shape or other.

4217. In relation to electrical currents and their nature, how slow a current must be in an electrolyte compared to that in a metal? For instance, if a cubical inch of water be electrolyzed by electrodes applied at two opposite surfaces, then the elements will have travelled in opposite directions only a tenth of an inch by the time that a tenth of the water is decomposed, and if we imagine the electricity associated with the particles, it will have advanced only a tenth of an inch too. Yet what an enormous current or discharge, according to our common notions, must have taken place, to decompose a tenth of a cubical inch of water or $27\frac{1}{2}$ grains.

4218. Electrolytic action gives one an opportunity of identifying a particular portion of Electricity (as it were) in a current and so subjecting it to certain considerations of importance. Consider this in relation to the Magnetic force of a current.

4219. Ampère's lateral attraction of similar currents is directly opposed to the lateral repulsion of the lines of the pre-existing induction, just as the attraction and tension of direct induction is opposed to the cessation of attraction and tension of the following discharge. The two first must therefore be connected, and the former result is probably a direct consequence of the latter (related together as action and reaction) at the moment the latter is let down.

4220. There may be two electricities in the particles of matter; that is a point still undecided. But it is not less important to trace the intimate relations of these fluids or forces to the particles and the laws which govern them.

4221. What are the causes and forces of the attraction and repulsion, and what constitutes their difference?

4222. In a decomposing electrolyte, all the particles in the course of the current, i.e. in the line joining the electrodes, are probably in an equal state of tension, indeed appears as if they must be so. Hence easy to see why transfer of power is more difficult at the anode and cathode, if the gas or element is evolved, than in the middle of the course where the particles combine.

4223. As inductive tension goes down when two inducing surfaces are connected, the state of the particles of the di-electric must be sustained per force, i.e. they tend to keep their natural state, or if induced out of it, tend to return to it. What is the force and its condition which thus keeps the particles in this certain natural state? What state of the Electric power is it, and how is that state related to the evolution or excitation state.

4224. The probable nature of *intensity* is in a condition of each particle or particles; the higher the degree of this condition the higher the intensity.

4225. In Electrolyzation, tension first acquired and when that has risen to a certain degree, evolution or discharge.

4226. May perhaps by some arrangement of apparatus obtain a standard of tension here; as by comparing the tension in an electrolyte with the current in an associated wire, etc. etc.

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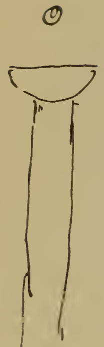
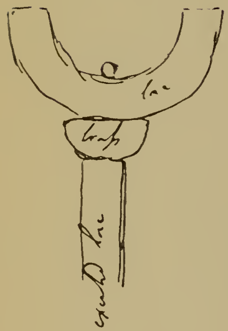


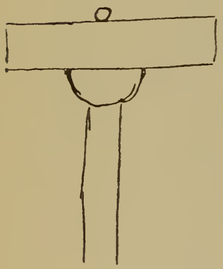
4227. Expts. on curved lines of induction, with other bodies than air.

4228. *Carbonic acid* in a jar—obtained good results after some time—but glass conducts so well that if a moderate jar be used, the induction to the sides takes up all that would otherwise go round the ball or rather hemisphere, for I used it. Obtained good results in very large vessels full and open at top. Also by letting an abundant stream of C.A. descend on to the parts, whilst the induction contact made.

4229. Hydrogen. Used an abundan[t] stream from a metal pipe, wide, and employed the pipe to make contact with carrier ball. Just as strong effects as in Air.



4230. Now experimented with Solid bodies. The excited lac cylinder and the brass hemisphere on it were arranged as in former cases (   ). Then the alcohol shell lac hemispherical cup was tested by the carrier ball and found free from charge at all parts. It was carefully placed as in the figure, the carrier ball put near it within—uninsulated—insulated—removed and found *Positive* as in former cases. The shell lac was then removed, re-examined and found without charge. Hence curved induction takes place through shell lac.



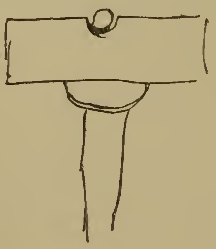
4231. *Flint glass*—a thick piece well dried and varnished with shell lac solution was used. Curved induction took place through it. It required much care to free the warm glass from previous electricity. This was done by breathing all over it. The glass was *without* charge both *before* and *after*.

4232*. *Sulphur*. The same result. The same precautions were taken. Sulphur can be beautiful[ly] discharged by breathing on to it.

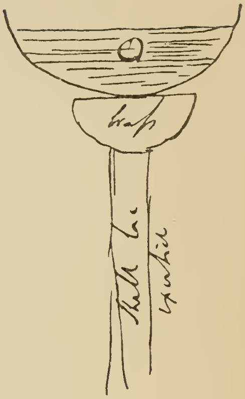
4233. I cannot help thinking that the charge taken by the carrier ball in these cases was stronger than through air. Shall perhaps be able to arrange some new form of experiment by using differences of inductive capacities. Must not forget this point.

4234. *Spermaceti*. Used the thick hemispherical cup of this substance and obtained good results of induction through it in curved lines. Must examine peculiar state of spermaceti very closely.

* [4232]



4235. *Oil of turpentine*—in the thin well varnished glass cup (   ). Ascertained first that the glass of cup as varnished did not conduct; then arranged it thus. The ball at place marked took a charge as in former cases—and also when higher, as at the surface of the fluid. Hence curved induction here also.



4236. Excited the lac cylinder strongly for half an hour, examg. it from time to time to see that the state was retained. Then by breathing and wiping, quickly discharged it (   ); found it unexcited: but being now left, in 5 minutes no return charge had appeared, no peculiar state—nor in ½ an hour. Repeated the experiment, being exceedingly careful to discharge the shell lac *all over* before hand, examg. it carefully. Then charged it very highly for ¼ of an hour, discharged it quickly and well, and then no return in any time.

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4237. In dielectrics under induction, the form of the particles may go for something, as in sensible conductors.

4238. The particles are probably polarized as so many associated *conducting* portions—as so many insulated conductors, and in this respect consider experimentally what the action of many small conductors under induction and free to move laterally would be—here obtain evidence of the lines of inductive force probably.

4239. The action of heat in causing discharge of inductive condition probably the same as the action of same agent, heat, when it causes union of chemical particles, i.e. when it enables the excited powers under induction to discharge, and so let the particle[s] unite.

4240. The heat of same electricity is different in different conductors; hence heat of electro-chemical equivalents when combining may vary the one from another, i.e. when electro-chemical equivalents combine to produce combustion—it does not follow that the heat must be equal because the exciting powers are equal.

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4241. I have cast a hemisphere cup of borate of lead in platina vessels in hopes of obtaining a good substance for insulation and peculiar state; but after all my expence and trouble, it has cracked so much in the cooling that it is useless. It conducts very considerably and I believe because many of the cracks running from the inner to the outer platina are vacua (air not getting in) and so conduct. The substance itself when sound insulates well.

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4242. I have fitted up fresh shell lac stems to app. i and ii, in which the metal wires are thin and of soft copper, the terminal ends only being large, to hold a screw worm for the balls. Have put the stems into the apparatus and find that it is a proper thing to make the sockets holding them thin, or else the metal in cooling cracks the shell lac. No. i has a thicker socket than No. ii, and its stem always fails first.

4243. Tried App. i and ii with these stems:

i		balls 336° touched at 6′	ii		
6′	above 497°		6	above 497°	
7′	was 490°		9	was 482°	5·0
12′	” 463°	5·4	14	” 480°	0·4
17′	” 455	1·6	19	” 473°	1·4
27′	” 434	2·1	29	” 450°	2·3
37′	” 405	2·9	39	” 422°	2·8

These app. will do for lower charges.

4244. Have had a wooden (box) apparatus made and a wooden inner ball, with which to observe effect of conductors. Have also put in a shell lac stem, etc., but it does not insulate well, for results were thus:

at 20′	charge was 460	
23′	” ” 392	23°
27′	” ” 302	22·5

Must ascertain hereafter whether this effect is due to imperfect stem or to action of surface of the wood within upon the induction.

4245. Now compared Air and sulphur, using a good sulphur hemisphere in App. ii. It was perfectly cleared from electricity before hand.

i, Air ii, Sulphur
balls 280°
0 . .
. . 0°
438° . .
434° . .
divided quickly
. . 162°
164° . .
. . 160° hence did not lose fast or conduct.
162° . .
. . 0° after discharge.
0° . . . . . . after discharge.
164° for i, Air
162° for ii, Sulphur } the half of divided charge is 217°
Air in i has lost 270°
Sulphur in ii has gained 162° } capacities are as { 1·00 / 1·66

4246. Again . . . .

i, Air ii, Sulphur
balls as before
0° . .
. . 0°
. . 395°
. . 388°
divided quickly took
237 . .
. . 238
0 . . . . . 0 } after discharge.
237 for i, Air
238 for ii, Sulphur } 194° is half the divided charge.
Air in i has gained 237°
Sulphur in ii lost 150 } capacities are as { 1·00 / 1·58

These perfectly consistent.

4247. Now experimented on sulphur as able to acquire the peculiar state, leaving it in App. ii and charging it as before.

balls 360°
At 6′ charged to 665°
12′ it was . . 650° . . 2·5
20′ ” 625° . . 3·12
26′ ” 590° . . 5·8

Loss is but small here, there is but little conducting power: is as good as if air present—hence probably little assumption of the peculiar state.

4248. Then quickly discharged the apparatus and instantly took a sample by the carrier—this

at 27′ was . . 2°
at 28′ had risen to 11°
30′ „ „ 14°
32′ „ „ 16°
34′ „ „ 17°
36′ was . . 17°·8
38′ „ . . 17°·5 then discharged the app. again and found indication was . . 2°, and this was the amount of stem effect—for the carrier at *d* rose higher still.

Hence sulphur does take on the state but only in a small degree.

4249. Must try this peculiar state with dielectrics in good contact with the conductors: a coated plate for instance? But that is tried in the residuary discharge of a leyden battery.

4250. *Spermaceti.* Experimented with the hemisphere of spermaceti (   ), for it appeared from former experiments that spermaceti would shew this effect in a high degree. Put it therefore into app. ii.

4251. Spermaceti in app. ii, balls about 300°.

	At 36′	charge was	544°	
	38′	„ „	385°	. . 79·5
	40′	„ „	314°	. . 35·5
recharged	42′	„ „	662°	. .
	44′	„ „	483°	. . 89·5
	46′	„ „	402°	. . 40·5
	48′	„ „	350°	. . 26·0
	50′	„ „	320°	. . 15·0
recharged	52′	„ „	627°	. .
	54′	„ „	482°	. . 72·5
	56′	„ „	420°	. . 31·0
	58′	„ „	368°	. . 26·0
	60′	„ „	337°	. . 15·5
	62′	„ „	316°	. . 10·5
	64′	„ „	285°	. . 15·5

Then discharged the app. and took observation instantly.

At 5′ was	0	At 11′ was	98
7 „	82	12 „	98
8 „	90	14 „	98
9 „	96	16 „	97; then again discharged the app.
10 „	97	and found it	0 even at *d*.

4252. Now charged the app. for a few seconds, then instantly discharged and took observations; balls 360°.

at 34′ was 0
35 „ 52
37 „ 68
38 „ 68 then discharged and found it 0°.

Hence short charge produces the state in spermaceti.

4253. Again charged spermaceti for a moment: discharged and made observations as quickly in succession as I could.

0°
40°
54°
56°
60°
58°

4254. Again, it takes the state quickly. Observe however that when time is allowed for effect of the charge, the return action lasts for a longer time and the return charge is higher.

4255. All this may be due to a charge of the dielectric, the two parts next the coating taking up the two opposite state[s] by conduction, as electrics are known to do in other cases. This will be due to the *coercitive force* of the two powers in the coatings, and when this is removed by their discharge, then though part of the power may travel on and neutralize within the dielectric, completing the act of induction, part may return outwards and reproduce the charged state. All the phenomena thus far agree with this view.

4256. Test the view and the opposite notion of a peculiar state by using a double plate of spermaceti. If the present view correct, each half plate will have its own state, one P., one N. If a peculiar condition of the particles exists, then each half will shew both P. and N. on its opposite surfaces.

4257. Experimented on curved inductive action through borate of lead—found it to occur just as in former cases.

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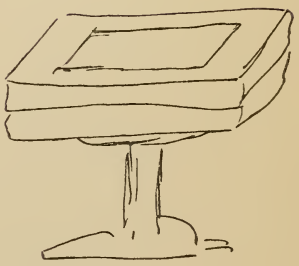

4258. Prepared two plates of Spermaceti $\frac{1}{2}$ inch thick and eight inches square, flattened a side of each to come together, coated about 36 square inches of the other two sides with tin foil—put silk thread round the edge of each, so as to insulate them at pleasure—put them together with the coated sides outwards—uninsulated one coating and charged the other Pos.—then discharged and took instant state by the carrier and found no electricity; yet on waiting a minute or two found plenty of return electricity as in former cases. So that the double plate of spermaceti can produce the peculiar effect.

4259. Now charged them (when together) again; then discharged quickly and instantly separated and insulated the upper plate. Examd. it and found by the carrier it was Positive altogether, i.e. the tin foil surface was pos. by contact and the other surface was pos. also, for it rendered the carrier ball neg. by induction. Hence the whole of this plate, constituting one half the compound plate, was Positive, and doubtless the other half was altogether negative.

4260. When after the charge and discharge of the united plates, the upper was separated, its tin foil could instantly give a considerable spark to the finger, of Pos. Electricity, shewing that the Pos. power, which before had been engaged towards the Neg. power by induction in the other half or lower plate, was by the separation at once set free to act on other bodies by induction. It also shewed that the lower half was Neg., and this was further proved, for on putting down the upper plate and its coating, an electrophorus action came on, and on touching the upper tin foil a spark went to it, because of its Neg. state on the upper surface—then raising it, a pos. spark came from it as before.

4261. Hence clear that, with peculiar state of spermaceti, all depends upon the two halves assuming opposite states to some depth, and this is no doubt the case with glass, sulphur, shell lac, etc. The whole is therefore a case of induction and not a peculiar state—i.e. a case of induction involvg. penetration and conduction to a certain depth in the Electric.

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4262. If the inductive force of the same quantity of electricity be changed in a *given space* by change of the dielectric, what change, if any, will occur in the corresponding transverse force?

4263. In respect to the restraining power of air or other dielectrics over discharge between two charged surfaces, we have to consider the discharge

in different dielectrics,
at different distances,
at different temperatures,
at different pressures (for gases),
and on some of these points Harris has worked.

4264. References to *Harris' first paper* in Phil. Trans., 1834. It is an investigation of the laws of *Inductive action in air*, p. 214.

4265. Tension and intensity, pp. 222.

4266. His Electrometer in vacuo, pp. 223, 224.

4267. Effect of variable atmosphere in restraining discharge, p. 227, 229, 242—consider p. 227, etc.

4268. Discharge through Air, p. 225, etc. important.

4269. Gives the required intensity to discharge across air at given pressures, p. 229, 242. Vacuo question, 243.

4270. Insulating or restraining power of heated air, 229.

4271. Effect of form or extension on the charge, p. 232.

4272. Induction in *right lines*, p. 239.

4273. Induction does not vary with the pressure of air, 237, 244.

4274. *Harris, second paper*. Phil. Trans., 1836, p. 417. Is an experimental examination of Coulomb's indications by a proof plane. Electricity on a plane or sphere, p. 437, etc. etc.

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4275. On reading Article Electy. in Supp. to Ency. Britannica[1], Poisson's theory as at present applied does not represent the curved cases. More like atmospheres of former times. But recent philosophers thought these could not be in glass, which does not permit passage of Electy., p. 79—assumes that the effect is influence at a distance, p. 79—of electy. in the conductor only. Induction is due to the action of the covering electrical strata. The theory assumes charge without induction, p. 82—that retention is an effect of air—discharge is independant of induction.

4276. As to difference of charge on different conductors—try my apparatus of wood.

4277. Why does smaller ball give the highest charge? See 3920, 2, 4, 6, of my M.S. notes of Expts., i.e. of these notes.

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[1] Supplement to Third Edition, 1801.

4278. There should be greater attraction through shell lac than through Air.

4279. As to tension, there should be increase of it when shell lac induction is converted into air induction. See p. 51 of Eleventh series, M.S.

4280. Can attraction and repulsion of balls, etc. in air be due to the lateral repulsion of the lines of inductive force?

4281. Light of the Electric Spark. Remember Biot, view of it at End of Article Electy. in Sup. to Ency. Britannica.

4282. If there were a specific capacity (inductive) amongst gases, would not two gases, when mixed, discharge from the incongruity of their inductive action? If there be differences between solids and fluids, would not this difference occasion discharge? Query the action of salts and acids in water on this principle?

4283. Are not the forces of charged bodies all external to the conductors?

4284. Vibratory theory of Electy., Ency. Britan.[1], Electy. 106, or Vol. vi, p. 460.

4285. My theory of induction does not decide whether Electricity is a power or a fluid or fluids, but leaves that open.

4286. The great point of distinction and power in the theory is the making the *dielectric* of essential importance, and not merely an accident almost. Hence pressure of the air, that awkward expression, disappears in my view—same advantage in chemical action—same in all inductive phenomena. Even metals are to me *di-electrics*, but how would the pressure of the air principle apply here, or avail here?

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4287. A mode of measuring the requisite intensity necessary for Electrolyzation may perhaps be obtained by increasing the length of interposed electrolyte until the decomposing action by a volta meter in another part of the circuit is brought to one standard degree—a constant battery being used for the purpose.

4288. As many different modes as there are of causing discharge, so many different modes have we of analyzing or rather testing the nature of the *current*. Also as many different modes as we have of observing current by its effects, so many different way[s] can we examine it. Modes of discharge are four. Effects are three, namely Electrolyzation, Magnetic action, heating power. So there are apparently twelve combinations by which to examine constancy of current.

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[1] Third Edition, 1797.

4289. As the Magnet or Magnetic action, which is used as a test of the current, remains unchanged during the variation of the mode of discharge, it shews that these modes are not each a particular act and condition, but are identical in their general effect, that discharge (and therefore much more, current) is of a very general and unchangeable nature. Not like heat for instance, giving a variable result, but all the forms givg. a definite and the same result.

4290. Cannot as yet say in a wire that the tension is let down (i.e. with a voltaic battery), for the tension and discharge acquire a constant state at last, which continues durg. the action—so Mag. not due to a fall from a higher to a lower state of tension. Do not know enough about that point at present, but a little thought may clear all up.

4291. There is a beautiful constancy of current under *every* mode of discharge. The two powers every where quite inseperable. The instant a particle of matter moves, as in carrying currents, or in any other way—there the two powers exist and are shewn by peculiar effect. This a full proof that, during the prior induction, they were every where in the lines of induction.

4292. At the first moment of discharge, as in a spark, that discharge would probably be dark, but that all the rest of the electricity follows it because of the facility of passage there, and so it becomes a bright spark. Not that that quantity of electricity is required there, at the first moment, but is led there by the circumstances of discharge.

4293. There are many illustrations of this. Suppose two square inches of inductive surfaces were discharged by balls half an inch apart, and then 200 square inches of such surfaces were discharged by the same balls, etc. In both cases the discharge would commence at the same intensity of inductive action, but the quantity passing would be very different. And as 99 parts, in the latter case, would be led to the place of discharge by the first effort, so in the former case the first effort is due probably to a very small portion of the electricity—in fact only to that existing at the point of *highest* inductive tension—the moment before the discharge. All the rest merely follows in the same course.

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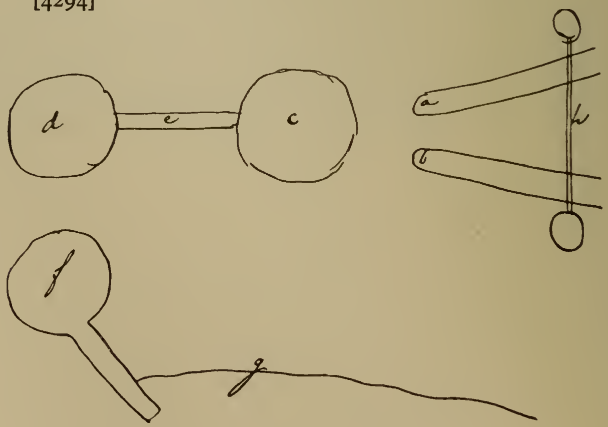
4294*. Made some expts. on this point and the mutual influence of simultaneous sparks. Two equal Leyden Jars had thick copper rods attached to their balls. The extreme ends of these rods *a* and *b* were rounded. The two jars were placed on a sheet of tin foil, and when the brass rod *h* was across the rods *a* and *b*, could be charged as one battery, and then by removg. *h* could be discharged in two sparks. *c*, *d* and *e* are two brass balls and a metal rod, the whole insulated. *f* is a metal ball, uninsulated. When the jars were charged and *h* removed, by bring. *f* to *d* a simultaneous discharge of both jars occurred in two sparks varying according to circumstances, i.e. if *c* was as near to *a* and *b* as they were to each other, then *a* and *b* each gave its own spark to *c*: but if the distance from *a* to *b* was about six tenths, or less, of that between the ends and *c*, then a spark would pass between *a* and *b*, discharging one of the jars, and another between *c* and either *a* or *b*, discharging both the jars; i.e. if *a* was a little nearer or a little more favourably situated than *b*, the latter would make it a step for the discharge to *c*, notwithstandg. the length of the course was so greatly increased by the circumstance. And this was because the spark which tended to pass first did, by it[s] first act of discharge, so facilitate the passage there that all the rest ran in to it.

4295. When I obtained two separate sparks, I think they tended towards each other in about two thirds of the cases, and tended more or less outwards in the remaing. third, but these experiments are to be repeated with a better apparatus.

4296. Hence evident facility in path of spark to discharge other and waiting electricity.

* [4294]



4297. Therefore probably that place of discharge is at first dark, but becomes bright by accumulation of electricity in the passage.

4298. We see in brushes this accumulation, by the junction of many branches in few, and these in one root, which is often a spark at the surface of the metal conductor.

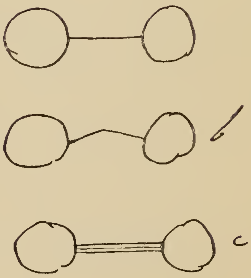
4299. By taking discharge between excited glass and excited wax, can probably get a discharge brush at each end and spark in the middle, shewing the same thing well.

4300. The discharge from an insulator is in this view very important.

4301. The same thing must occur in a thunder storm, when the electricity collects from various parts of a diffuse mass consisting of mixed insulating and conducting matter; to make one single flash.

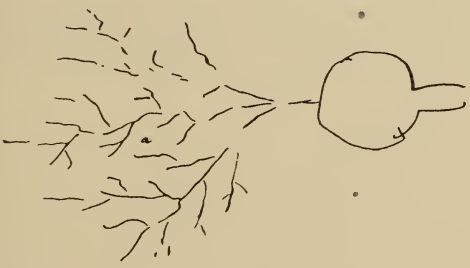
4302*. Shall have to consider how the discharge takes place between the bright and dark parts, in a brush for instance, between the part *a*, the farthest removed from a luminous discharge, and the parts where discharge is evidently passing. Is it by *dark conduction* (   )? Is it by moving of the air? Or by any act of induction amongst the parts themselves independantly of other parts, or do they remain charged to a certain degree and take up their right place in the series the instant the discharge is over? See 4317.

4303. I think time is concerned in the passing of a spark; but when simple and direct, as between metallic balls, I should rather look for it as continuing the time of the whole spark, not as giving existence first at the balls and then in the middle. If a spark be thus with stationary balls or with a steady image, I think Wheatstone's apparatus ought not to shew it thus, as at *b*, but thicker, rather as at *c*, the time being employed in continuing the whole spark, not in giving existence to one part before the other. I think this is the case in Wheatstone's middle spark.



4304. Still, in a brushy spark, it is possible that time might be discovered, affecting the prior existence of one part to another, for it is quite clear that in discharge to air, the induction of different

* [4302]



parts may be let down gradually or even in separate portions. I must send out a straight constant brush, and then by analysing it by movg. the eye in different directions across it, see whether I can give it a general curve first one way and then the other. Is very likely.

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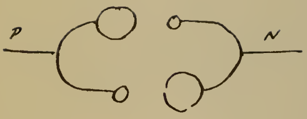
4305. Must trace the point of *time* in a discharge from brush upwards to spark. In my view, brush discharge must begin at the root first, or at least continue there longest. Brush time therefore longest.

4306. I doubt the relations of balls of fire from the atmosphere as a form of electricity altogether.

4307. Observe the brush form in long tube and rarefied air.

4308. In Pos. and Neg. discharge in air, the Pos. ball gives a longer and larger spark than the Neg., i.e. it contains more electric force, for the discharges are much fewer in number. But is it that Pos. ball in discharging more readily begins to discharge at a lower intensity than the Neg. ball, or when it has begun, at the same intensity throws off more in the single discharge?

4309. The Neg. ball gives more brushes than the Pos. ball in the same time, hence each discharge is smaller. Suppose the intensity of the P. ball be 50 and 30 at the beginning and end of a brush, that of N. ball may be 50 and 45, or it may be 35 and 30, or any interval between these or about them.



4310. What is the real state of things? Find it out by making P and N alternately Pos. and Neg. and observg. where the sparks occur, and whether varyg. the distance makes one surpass another.

4311. As to positive and negative ramifications, their particular condition and freedom of formation, at a part *not in contact* with the conductor but distant from it, must surely be due to the nature of the dielectric and its relation to the electric forces, not to the form or shape of the conductor itself.

4312. Therefore a reason why it should not be due to two particular fluids at these conductors: the great portion of effect is produced afterwards in the air.

4313. It is probably due to the difference in facility with which the air is charged Positively or Negatively. If it is more facil to charge air *neg.*, it will of course be more facil to discharge air charged *Positively.*

4314. Can easily imagine how the difference of Pos. and Neg. effect in discharge may depend upon the way in which particles of air polarize in the previous act of induction. Thus if the Negative part be diffuse and spreading, and the positive part be concentrated, or vice versa. Even the form of the particles may have an influence here—and this again may be connected with chemical forces and affinity.

4315. When Air is charged by a brush, it then has to discharge against the opposed ball or walls of the place or otherwise.

4316. Must experiment on the mode by which a particle of air, when charged and free to move, is discharged. Use oil of turpentine and coloured streams or coloured silk.

4317. Air mixes throughout very freely, but probably there are but few particles of air electrified and these highly (at the maximum tension degree), and these being repelled, etc., the rest or neighbng. parts are drawn into a stream by the current. See 4302.

4318. The electrified particles cannot induce to their neighbours, but outwards just as before. They do not bring their neighbours on each side into opposite states; the induction force and its lines are still outwards to the neighbouring conducting matter.

4319. The particles of air when electrified are repelled and attracted as particles of electrified dust would be in the same circumstances. Each is its own centre of inductive action, and will quickly travel to the next conductor, which by discharging sets all right again.

4320. But few particles travel probably; the rest of the air is moved more or less only. Each particle in the air may be like Franklin's ball, which being charged and whirled, lost no power.

4321. I had alternating effects of facility and difficulty on the P. and N. surface of discharge with E. Machine (2989, 90). This was due to the charged state of the air about and is strong experimental proof of that charge.

4322. This probably not considered in Belli's experiments of discharge. Query in mine (2955, etc.).

The falling back of electr. in (2975, etc., 2979) due to the same charged state of the air.

4323. Unipolarity effects may be connected with the different facility with which different dielectrics charge at the Pos. and Neg. surfaces.

4324. As to the difference of the brush in *different gases*, it is almost certainly related to specific difference of the qualities of these gases.

4325. Must make the P. and N. ball and point experiment (   ) in different gases, especially in oxygen and Carb. acid.

4326*. Compare discharging or retaining power of airs or gases by using two collateral places of discharge with standard balls, and keeping the air distance constant. Then vary the gas distance till equal to the air distance in insulating effect.

4327. Perhaps also vary the size of the ball, making first large and then small P. and N.

4328. The further a brush extends the further is the discharge carried out. This may vary in gases, as in Nitrogen and Mur. acid, and yet the intensity required for the first discharge not vary.

4329. Discharge is a positive action. Insulation the deficiency or absence of this action.

4330. Reasons for considering Electricity an indicator of truly simple elements. Anions and cations are elements (except perhaps cyanogen). Simple relation of Electricity to these. If there are other elements, it would seem that there must be another relation of Electricity to them, different to what we know.

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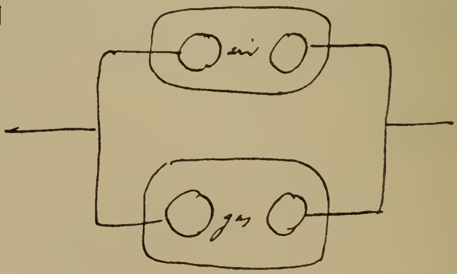
4331. Davy in his paper on conduction, Phil. Trans., 1821, at the end, evidently thought that different numbers of plates in a Voltaic battery gave different *quantities* of Electricity. See p. 432, etc. Hence some curious expectations and confusions of intensity with quantity, see vi, p. 434, etc.

4332. Harris considers induction as an exertion of *parallel* forces (in his case) operating in *right lines*. See his paper, Phil. Trans., 1834, p. 239, etc.

4333. *Induction* an action *at a distance*. See Becquerell, in his Traité, Vol. ii, p. 177.

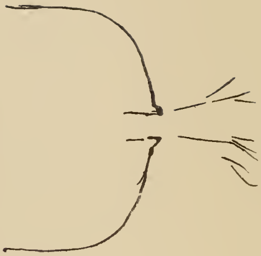
* [4326]



1 JANUARY 1838.

4334. Have been experimenting this evening on time as an element in electric discharge.

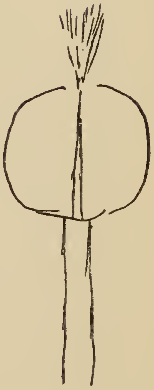
4335. Chose the brush from an expectation that time might appear there. Produced a good pos. brush from the end of our large brass conductor (2 inches diameter with irregular end); the brush was into free air, its rays about 4 inches long, separate, and the successive brushes were about as fast as I could repeat tut, tut, tut, etc. Their general form as a horizontal brush was very steady and good, thus[*].



4336. Looking at this brush in a mirror, it was well seen. Then moving the mirror to and fro on a horizontal axis, the elementary brushes were separated, standing in order on a vertical line. Now if the discharge of each brush took a sensible time, then the brush, instead of being quite straight out, should seem bent generally in one direction; i.e. bent towards the place of the next succeeding brush.

4337[†]. This effect I think I perceived—sometimes very distinctly. I endeavoured to separate it from any irregular motion of the mirror, and think it could not be referred to such a cause. At the same time, it is difficult to be very positive, because of the feeble light and in some degree indefinite form of the brush.

4338. I then obtained a more compressed brush, from a large ball with a hole and a point in its upper part, and examined it in the same way. Its recurrences were much quicker than the former, but still I thought I obtained the apparent flexure of the brush, as if a wind passed over the line of brushes, bending them all a little in one direction.



4339. When brushes are large or when bad conductors are included in the conducting matter, here and there the brushes are by no means isochronous, but often very irregular, as thus[‡].

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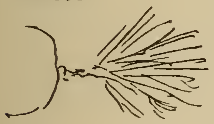
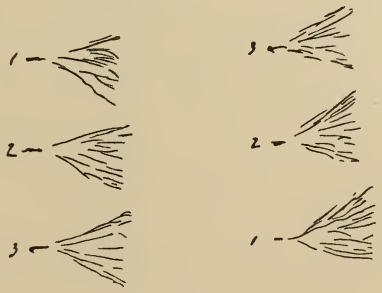
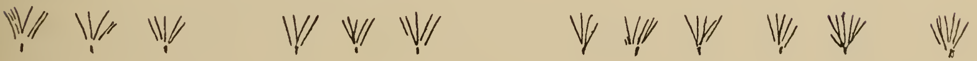
[*] [4335]



[†] [4337]



[‡] [4339]



They vary also much as to the character of their roots, but can always be governed. All the variations can be traced easily to the condition of the inductive forces.

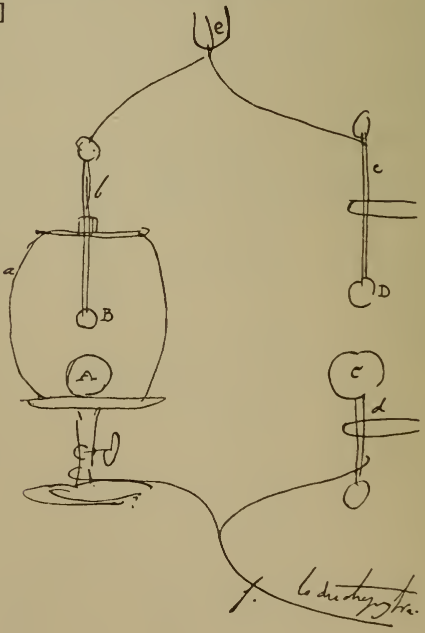
4 JANUARY 1838.

4340*. Have had an apparatus made for discharges in air and in gases, so as to compare. *a*, a glass receiver well varnished; *b*, a plate and sliding wire; *c* and *d*, two metal rods with balls insulated; *e*, conductor at machine rendered Pos. or Neg. at pleasure; *f*, discharging train. So now, when conductor *e* made pos., sparks would pass either at balls in gas or balls in air, and as the latter are moveable and the former were retained fixed at 0·62 of inch, the latter could be adjusted so as to let all the sparks pass there, or all in the gas under trial, and the distance in air so measured and required becomes a measure of the resistance in the gas under examination. I found that, whilst ball[s] were constant in the receiver, still variation might be made in air distance and yet sparks pass both at one and the other. To understd. this, observe first that the balls were constantly the same,

ball A being in diameter 1·95 inches
B " " " 0·96
C " " " 2·02
D " " " 0·93

Also that the interval in the gas, which was 0·62 of an inch, was *constant*—but that air interval could be changed and shall be expressed by the numbers now to be used.

* [4340]



4341. When either Air, Nitrogen or Oxygen was in the receiver, and the air interval between balls C and D was 0·6 of an inch, the sparks on working the machine would pass sometimes in the receiver and sometimes in the air, shewing an approach to equality of induction in the two cases; but on rendering the air distance smaller and smaller until sparks hardly ever passed in the receiver, it could be reduced to 0·56 of an inch, and on rendng. it larger and larger until sparks hardly ever passed in the air, it could be increased to 0·79 in one case; this range of 0·23 being one in which sparks would pass occasionally both in the receiver and in the open air. This range must be noticed and recorded.

4342. Then making the balls B and D either Pos. or Neg. from the machine was expected to produce a difference in different gas. So that this also was observed and recorded in the following experiments.

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4343. *See* 4549.

		of inch		of inch	
Air, B and D	Pos.	0·60	·19	0·79	
,, ,,	Neg.	0·59	·09	0·68	
Oxygen ,,	Pos.	0·41	·19	0·60	spark good as to light, very bright.
,, ,,	Neg.	0·50	·02	0·52	
Nitrogen ,,	Pos.	0·55	·13	0·68	
,, ,,	Neg.	0·59	·11	0·70	
Hydrogen ,,	Pos.	0·30	·14	0·44	spark poor in light and brushy.
,, ,,	Neg.	0·25	·05	0·30	spark poorer still much.
Carbonic acid	Pos.	0·56	·16	0·72	spark fair and good.
,, ,,	Neg.	0·58	·02	0·60	spark fair.
Olefiant gas	Pos.	0·64	·22	0·86	spark bright but rarely in middle—curious.
,, ,,	Neg.	0·69	·08	0·77	spark worse than when *pos.*, still runs to one side, singular deviation in the middle.
Coal gas ,,	Pos.	0·37	·24	0·61	spark always pale, often very pale and brushy.
,, ,,	Neg.	0·47	·11	0·58	spark easier obtained than when *Pos.*
Muriatic Gas	Pos.	0·89	·43	1·32	spark fine.
,, ,,	Neg.	0·67	·08	0·75	

4344. These expts. were made at once and with care—at other times other results were obtained, thus:

Carb. acid	Pos. gave	0·51	1·05
Olefiant gas	Pos. „	0·66	1·27
Hydrogen	Pos. „	0·23	0·57

4345. With regard to the above results, the following remarks may be made.

4346. Whether the electricity from the machine passed as a *continuous* or a *spark current* to conductor *e*, the effects generally were the *same*.

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4347. In many cases, when a spark had passed at either place, then many more passed in succession at the same place. If it passed first in air, stopping the machine a moment and then renewing working, it might commence passing in the vessel or in air, but the following sparks were at the same place as the first. The discharge of a spark indicated that the next would most likely pass there also, and when the machine was worked quickly, the sparks almost always *continued* to occur at the same interval, as if things were prepared there for it. This preparation might be either in the warmth of the air, heated by the preceeding spark, or in little particles of dust drawn into the circuit, or in something unperceived as yet.

4348. It is striking that with regard to Air and some other gases, when they are in the glass, and air at the open interval, the latter does not suffer nearly so much variation as when some other gases are in the vessel. Thus with air, oxygen, Nitrogen, Hydrogen and Carbonic acid, the range is not so great as with Oleft. gas, coal gas and Muriatic acid gas.

4349. One would have expected that there would be only two certain distances, one for each interval, where the discharge might happen either at one or the other, and that the least alteration of one would immediately make one predominate *constantly* over the other; thus making air interval larger would cause the other to predominate, or making air interval smaller would cause it always to occasion discharge. But that is not the case; a range is allowable; in the air case amounting to nearly 2 tenths of an inch on 6 tenths, and with Muriatic acid gas amounting to above four tenths on nine tenths. Now why is it that when a fixed interval will pass a spark that cannot go across 0·6 of air at one time, it will not pass a spark that can go across 0·8 of air immediately after, and apparently under exactly similar circumstances?

4350. Probably much of this variation depends upon particles of dust in the air drawn into and about the circuit. But it shews either in that and other natural causes great variation in the circumstances determining the sparks under common circumstances. Hence no wonder that the brush divides, etc. etc., and hence perhaps a reason for some of the forkedness of lightning.

4351. Again, it ought to be remarked that the differences when the smaller balls were made *Neg.* are much less than when they were made *positive.* Thus the range of simultaneous discharge is

	when Pos.	when Neg.	See 4550.
In Air	·19	·09	
Oxygen	·19	·02	
Nitrogen	·13	·11	
Hydrogen	·14	·05	
Carbonic acid	·16	·02	
Olefiant gas	·22	·08	
Coal gas	·24	·12	
Muriatic acid gas	·43	·08	

4352. But these experiments ought to be repeated, and as I suspect the parts of the glass vessel became charged and so affected the relation of the P. and N. ball as to inductive action—large glass vessel ought to be used—or perhaps even a metallic one, and both sparks ought to be in exactly similar vessels and the balls ought to be platina—all dust most carefully avoided and the gas let in freed from dust. It was dried.

4353. Though the air distance thus fails to be an accurate measure of the insulating effect of the gas distance, yet we may for the present assume the mean air distance as a measure, and it comes out thus when Pos. and Neg. (See 4551).

	Pos.	Neg.
Air	0·695	0·635
Oxygen	0·505	0·510
Nitrogen	0·615	0·645
Hydrogen	0·370	0·275
Carbonic acid	0·640	0·590
Olefiant gas	0·750	0·730
Coal gas	0·490	0·525
Muriatic acid gas	1·105	0·72

4354. As the results are not pretending to be accurate, but useful mainly as to the *order*, I may put down other three results as to some gases (   ).

Hydrogen	0·400
Carbonic acid	0·780
Olefiant gas	0·960

4355. Hence it seems very evident that the gases have specific qualities of insulation, for as air is included, the above numbers are comparable with each other, and express directly the difference each gas presents. Now it is not as the Gravity, for

S.G.	small ball *Positive.*	insulating power.	S.G.	small ball *Negative.*	insulating power.
1·0	Hydrogen . .	0·370	1·0	Hydrogen . . .	0·275
7·6?	Coal gas . . .	0·490	16·0	Oxygen . . .	0·510
16·0	Oxygen . . .	0·505	7·6	Coal gas . . .	0·525
14·0	Nitrogen . . .	0·615	22·0	Carbonic acid . .	0·590
22·0	Carbonic acid .	0·640	15·2	Air	0·635
15·2	Air	0·695	14·0	Nitrogen . . .	0·645
14·0	Olefiant gas . .	0·750	18·5	Mur. Acid gas . .	0·720
18·5	Mur. Acid gas .	1·105	14·0	Oleft. gas . . .	0·730

for though hydrogen is the smallest, and therefore smaller than oxygen, Oxygen is much smaller than Nitrogen or than Olefiant gas—and Carbonic acid is much smaller than Olefiant gas or Mur. acid. Oxygen as a heavier and Olefiant as a lighter gas are in strong contrast with each other.

4356. Hence not pressure of atmosphere which keeps electricity in conductors, but peculiar properties enter into action; each gas is specific.

4357. Another striking result comes out also, still proving specific action of each medium in induction. Thus, when the inductive action is *positive*, it differs from that occurring when it is negative. Thus in Air, Hydrogen, Carbonic acid, Olefiant gas and Mur. acid gas, the mean tension rose higher when the small ball was *pos.* than when *Neg.* But in Oxygen, Nitrogen and coal gas, the reverse was the result. Now though the numbers cannot be trusted (as Air is on one side and oxygen and nitrogen on the other) and will require finer experiments, yet there are decided indications of specific action.

4358. So when M.A. Gas was in the Vessel and the air interval was 0·8 of an inch, on rendng. the small balls positive, all the discharge was through the Air, but on rendng. them Negative, it was all through the M.A. gas.

4359. So when the air connection was removed, and only that to the M.A. Gas continued, *Negative* charges passed easier through the acid gas than *positive* ones, and the reason was that when *pos.* the connecting wire gave brushes easily into the air, the spark passing difficultly through the gas—but when Neg., the wire gave no brushes and the spark passed easily through the gas. Must ascertain whether air discharge easily or difficultly the Pos. charge. This would seem to imply an easy pos. discharge whereas the table p. 977[1] shews a difficult one. The oxygen and Nitrogen there shew easy discharge however, the small ball being allways *pos.*

4360. In these expts., I have continually had my mind impressed with the feeling that the great portion of the electricity in a spark is merely incidental to it, a little only giving the essential timing and first condition of discharge.

4361. The relation of the gas effects to the retention of the electricity on the surface of conductors by the air's pressure is very important, and fully confutes that view.

20 JANUARY 1838. (See 31 Jany. 1838).

4362*. Have had an arrangement of large and small balls opposed to each other constructed, so that whilst those on the one hand were electrified directly *pos.* or *neg.*, those on the other became electric by induction and served as dischargers. Their dimensions were as marked in inches and parts, the interval between the large and small ball on the same side being   inches and the intervals *n* and *o* variable.

4363. At first R set was made Pos. from machine and L set neg. by induction (being connected with a discharging train), and when the intervals *n* and *o* were both 0·63, the discharges were first at one place and then at the other in nearly equal degrees.

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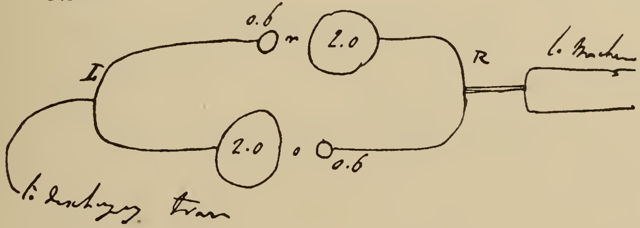
[1] par. 4355.

* [4362]



4364. When *n* was 0·63 and *o* 0·68, sparks were almost always at *n*. When *n* was 0·68 and *o* 0·70, sparks were almost always at *o*, so that the conditions at the interval *o* are apparently a little the best, for the mean of *n* is 65·5 and that of *o* 69 for mean equality of discharge.

4365. Hence *small Pos.* ball and *large Neg.* ball favour discharge more than *small Neg.* and *large Pos.*

4366*. Now tried the *o* arrangement alone, but had diminished the small ball so that *o* arrangement consisted of a small pos. ball 0·25 of inch in diameter, and a large Neg. ball 2 inches in diameter. At intervals of 2 inches or less at *o*, the discharge was always by spark; at interval of 2·2 inches it was almost always brush.

4367. Arrgd. the *n* interval in the same way, but now the limit for sparks was 0·6 of an inch and at 0·65 the Neg. brush appeared. Thus, the *small Pos. ball* can cause a much longer spark than the *small Neg. ball.*

4368. Made intervals *n* and *o* alike and 0·89 of inch in extent; sparks were always then between the small Pos. and the large Neg. at *o*.

4369. Made *o* 0·93 and *n* 0·67 of inch; then the neg. brush at *n* began to alternate and mingle with the spark at *o*, discharges being occasionally at both places.

4370. On the other hand, increased *o* until all discharge was at *n* as a neg. brush, and this was when *n* = 0·65 and *o* = 0·95. With a little less distance at *o*, spark discharge sometimes there. Carrying on the change in the same direction, there was occasional discharge at both places, until *n* = 0·72 and *o* = 0·76, but at that or higher ratios of distance the discharge was always at *o*. The mean for *n* = 68·5 and for *o* = 85·5, and these therefore indicate the relative facilities of the two intervals to occasion discharge. Here again, *small p* surpasses *small n* and more than before, *being smaller than before.*

4371. When the intervals at *n* and *o* were equal, discharge was never at *n* as neg. brush or spark, but discharge was often at *o* interval when it was larger than *n* interval. So that Pos. small ball must have an advantage, i.e. its discharge breaks through the air first, as if it were able to do so at a lower intensity.

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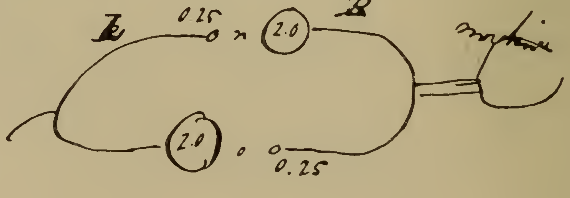
* [4366]



4372. Must, however, try these experiments by making the inductric ball *Neg.* and the inducteous balls *pos.*

4373. Again made *n* and *o* both 0·6. Then whether it was the right hand or the left hand balls that were rendered Positive, the discharge was always between the small *pos.* ball and the large Neg. ball.

4374. As by making the intervals greater and greater the discharge is at last by brush from both P. and N. small ball, so though the large balls take part in the effect, these two small balls may be compared to each other fairly—for the large balls at last pass away into the sides of the room. Hence it seems clear that the small Pos. surface dischges. more readily, i.e. at a lower intensity, than the small neg. surface.

4375. Now what is true of the first pos. surface will probably be true of the Pos. surfaces of the contiguous molecules of air, and hence probably the reason why at each discharge more passes away from the pos. than from the Negative surface. The two effects therefore of early discharge and much discharge connected together.

4376. Now made small ball still smaller than before, i.e. as in the margin*.

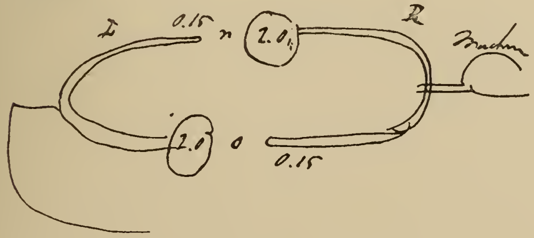
4377. Then the general effects were as before but the brushes much sooner, i.e. at shorter intervals.

4378†. When the two sets of balls were placed in a position so that the large balls were opposite, the large balls at *n* required to be brought much nearer to each other to produce a spark than the small balls at *o*; even to one half the distance or less. And when both were enlarged, so that a brush discharge appeared at *o*, then the interval there could be made five times or more that at *n*, and yet discharge occur at *o* by preference.

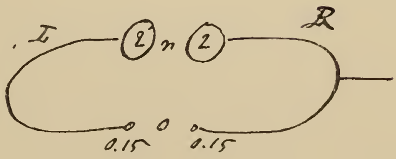
4379. No doubt therefore that intensity rises higher on small surfaces than on large, or at least that they favour discharge more than large: and by the former experiments, it appears that Small pos. favours it more than small Neg. The tension or intensity may surely be measured for the discharge by the electrometer on the conductor behind.

4380. In *air*, therefore, small Neg. surface requires higher tension and let[s] down less electricity than the small positive surface.

* [4376]

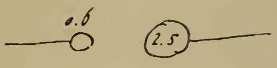


† [4378]



4381. The effect may depend on the Negative induction of contiguous air particles rising higher at the Pos. conductor than the Positive induction does towards the Negative conductor. It is most likely related to the polarity of the particles far more than to the electrified state of the conductor; i.e. it is more like to be the state of the particles than of the conductor that causes the whole effect.

4382. This will be confmd. if the conclusion that in different gases the effects are different is confirmed.



4383. Making the large ball Positive, the greatest spark interval was 0·9. After that succeeded the Neg. brush or perhaps even the glow. The Neg. breaks into brush very soon as to increase of interval, then cannot discharge enough to form a spark; so little goes off each time.

4384. There is no fall of Electrometer on the conductor without a brush or spark or carrying.

4385. Intensity at end and commencement both of a brush from a negative termination is higher than for a brush from the same termination rendered pos. in exactly similar circumstances.

4386. At such a distance as with a small prime conductor would give a brush, a jar charge should give a spark and yet with the same intensity at the commencement.

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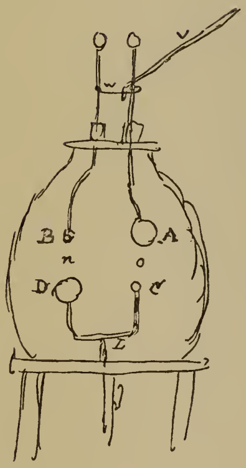
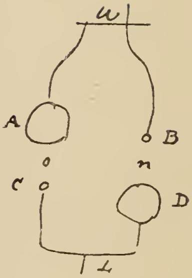


4387. Commenced a series of experiments with opposed large and small balls in air and some gases. The apparatus was of the following kind. A large air pump receiver was attached to an air pump and closed by a brass plate above, with two sliding wires in it. The receiver could be exausted and filled with any other gas than air, and such gas was always passed in through a drying tube containing chloride of calcium: L is a brass fork fixed in the pump plate and carrying 2 balls C and D, a large and a small one. Two other balls A and B were carried by two separate sliding wires moving independantly of each other, but connected by a joining wire w, and that connected by another wire v, which was attached to an insulated brass conductor that could be made Pos. or Neg. directly by means of a cylinder machine with 2 insulated conductors. The wires of A and B were graduated so as to read off by the application of a diagonal scale at the top of the sliding boxes, and tell the distances between the balls A and C and also B and D. The upper balls with their wires and the connecting wire w I will call altogether U. The air pump receiver was of such size that its diameter in the widest part was eleven inches: its height 10$\frac{1}{2}$ inches in the wide part: the distance between C and D 3$\frac{1}{4}$ inches: their height above the pump plate 5 inches: the distance between the balls A, B, C and D and the sides of the glass 1$\frac{3}{4}$ inches at least and often more when the experiments were in progress. I will call the intervals *n* and *o* as marked.



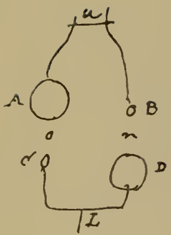
4388. At first made the balls A and D each 2 inches in diameter and B and C each 0·25 of an inch in diameter—*Air* being in the receiver and the jar placed so that the balls within were equally circumstanced as to any inductive action from without.

4389. Made the intervals *n* and *o* alike = 0·5 of inch—U *pos.*—then nearly equal discharges at *n* and *o*—if any difference, *n* a little more frequent than *o*. Made U *Neg.*—now all discharge at *n*; not one at *o*—as if small neg. discharged better than small pos. The discharge at this distance of 0·5 was always in sparks.

4390. Changed the small balls C and B for each other, all other things remaining the same, to see if any effect due to the particular ball. Made U *Neg.*; the discharge was at *n* as neg. brush constantly. Made U *Pos.*; discharge was still at *n* as spark and almost altogether—there was a little at *o*. Hence as small ball B was made both *pos.* and *neg.*, it would seem that discharge is rather more favoured at *n* than at *o*, perhaps from the influence of the inductive power of the glass. In judging therefore, must judge from average of *n* and *o*, U being made *pos.* and *neg.* in turn.

4391. Pos. and Neg. seem very much alike as to discharge intensity; not much difference apparently, if any, but know more hereafter.

4392. Assuming that the discharge always *begins* at the small ball—as it certainly does in the brush discharge—then I may speak of pos. and neg. discharge according as the small ball is *pos.* and *neg.*, and can then distinguish whether it is pos. or neg. inductrically or inducteously.



4393. Made U *Neg.* Threw *n* balls out of action by making distance great and observed the discharge at *o*. When the interval there was 1·1 inches, had sometimes brushes and sometimes sparks. Though *n* = 2 inches or more, often had discharge by Neg. brush there when discharge would not occur at *o* = 1·1 inches. But the sides of the glass interfere much both as charging and as conducting.

4394. Made U *Pos.*, with intervals left as before. All discharge was at *o* by Neg. brush on C. No discharge from B—hence really seems that Neg. ball discharges easiest.

Diminished *o* interval gradually—brush continued on C until *o* = 0·65 or 0·75 and then sometimes a spark—at 0·62 many sparks but some brushes.

4395. *For relative tendency of intervals to discharge.* Made *n* and *o* = 0·4. U *Pos.*—discharges about alike in frequency and in sparks at both places. U *Neg.*—discharge always at *n* or small Neg. ball as neg. spark—not at all at *o*.

4396. Made *n* and *o* = 0·6. U *Pos.*—discharge at *n* always by pos. spark. U *Neg.*—discharge at *n* always by Neg. brush.

4397. Hence *n* favours discharge, but the general result seems to shew that Neg. is more facil than Pos.

4398. Increased *n* interval a little; still it seemed most favourable to discharge whether U were *pos.* or *neg.*

4399. Made *n* and *o* = 0·8—U *Pos.*: discharge always at *n* by pos. brush. U *Neg.*; discharge always at *n* by Neg. brush.

4400. Some effect seems to depend upon which is Inductric but not much apparently upon whether the Inductric is positive or negative. I must repeat the experiments in the open air. There must be some mistake about them (   ).

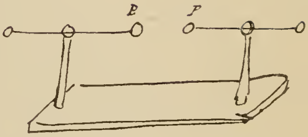
4401. A great difference between the Pos. and Neg. as to the interval at which the brush and spark change their characters. With regard to the brush Pos. or Neg., all seems to depend upon the quantity of Electricity which leaves each time, and perhaps this is the cause why the pos. spark continues to greater distances than the neg. spark—for because *more* leaves by a positive brush will govern the production of a spark for a longer time as intervals are increasing. There seems to be no other difference at present.

But must be very cautious, both in the experiments and the conclusions.

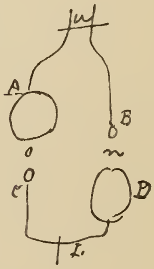
4402. Now made intervals *n* and *o* = 1 inch. Whether U were made Pos. or Neg. the same thing happened as before, namely, discharge always at *n* as either pos. or neg. brush.

4403. Remarked the change from spark to brush at *n* interval only (*o* being thrown out of action by great increase of distance). When U or small ball *was pos.*, there was spark at intervals less than 0·66 almost always—at 0·66 brush came on with a chance spark now and then. When U or small ball was *Neg.*, there was spark up to 0·46, then brush occasionl., and at 0·50 brush generally with a spark now and then. If small ball had been inducteously Pos. or Neg. (instead of inductrically) the change would probably have happened at other intervals; see this presently.

4404. Have arranged the discharger of the 4th instant (   ) so that it might be used as before, being so connected with the conductor that the discharge might either pass by it or through the air pump; made the balls E and F alike and 0·6 of inch in diameter and kept them at this in the rest of these comparative experiments.



4405. Interval *n* being 1·0 inch (and *o* out of use) U *was made Neg.*, and the interval in the open air gradually increased. All discharge was at it until it was 0·35, then an occasional discharge happd. at *n*, and when air interval was 0·39, all discharge was at *n*. Hence these the limits of the change of place of discharge; the measure of the discharge tension in air between the large and small balls B, D. When U *was Pos.*, then the change of place of discharge occurred when Air interval was 0·5. So that this implies a lower tension for dischge. of small Neg. surface than for that of small Pos. surface.



AIR.

4406. After these trial experiments, arranged for more comparative ones on *Air*, *Hydrogen*, *Oxygen*, *Nitrogen*, *Carbonic acid gas* and *coal gas*. Using the same apparatus, but I resolved to employ smaller balls or terminations for B and C, that the effect might be more distinct. *These were therefore now* 0·15 *of an inch in diameter*, A *and* D *being* 2 *inches as before. The discharge balls in the open air were* 0·6 *inches in diameter and I will call the interval there p.*

Air in Jar.

AIR. 4407. *Discharge compared with that in Air.* Made $n = 1$ inch; threw *o* out of action: U *Pos.*: Air interval $p =$ less than 0·4, very little dischge. at *n*; nearly all at *p*—when 0·4 the same—when 0·5 brush at *n* in jar and spark in air interval—this mixture went on a little even at higher air intervals. U *Neg.*: at less than 0·28 for *p*, all dischge. in air at *p*—at 0·31 some dischge. at *n*, at 0·33 and 0·40 all dischge. at *n*.

4408. So here apparently easier dischge. for *Neg.* than for *Pos.*

4409. *Relative discharge at n or o when equal* = 0·4. U *Pos.* Discharge in sparks at both places and nearly equal in times—rather more at *n* than at *o*—U *Neg.*—discharges principally at *n* but occasionally at *o*—at *n* often sparks, often brushes—at *o*, all sparks. So here *n* has advantage as before, and *pos.* does not discharge more freely than *Neg.*

4410. Made *n* and $o =$ 0·8 of inch—U *Pos.*: discharge altogether at *n* as pos. brush.—U *Neg.*: discharge altogether at *n* as Neg. brush.

4411. The result is that in Air in this apparatus there is not much difference.

4412. *Transition from spark to brush* at both *n* and *o* when U made both Pos. and Neg.

4413. At *n*, *ball* B *Pos.*—sparks freely beneath and up to 0·55, then at higher intervals Pos. sparks and brushes pretty well mingled.

4414. At *n*, *ball* B *Neg.*—sparks freely beneath 0·3—fairly at 0·3. At 0·32 the Neg. brush very constant. Hence Neg. brush sooner than Pos. brush when small ball B *inductric.*

4415. *At o, ball* A *Pos.* Sparks up to 0·4 and 0·42, but not higher; after that the Neg. brush.

4416. *At o, ball* A *Neg.* Sparks up to 0·75. Pos. brush mingled in at 0·77—at 0·83 and 0·9 Pos. brushes but often sparks. Hence Neg. brush sooner than pos. brush when small ball C *inducteous.* Hence also great difference due to whether the small or the large ball is inductric, and superiority in several respects of the latter.

OXYGEN. 4417. *Discharge compared with that in air.* Made *n* 1 inch, *o* being out of action. U *Neg.*: with *p* interval less than 0·27 or 0·27, OXYGEN.

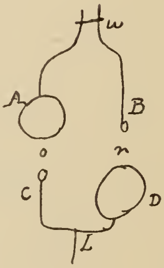
all discharge was as sparks in the air—with $p = 0{\cdot}3$ obtained a single spark in air, but otherwise all the rest at different times were in the oxygen at *n*.

4418. U *Pos.*: with the interval $p = 0{\cdot}3$ as left above, all discharge was in the air—with 0·33, most discharge in the air as spark and a little at *n* as brush (pos.)—same with 0·35 and 0·37 intervals—with 0·4 much discharge in air—much in the oxygen—same with 0·47—even at 0·52 an occasional spark in air but they were not frequent—this may be taken as the largest limit.

4419. Made *p* interval 0·3 again and U or ball B pos.—most of the discharge was in air, but there was some in oxygen. Then made ball B Neg.—now far more discharge in oxygen but there was some in the air. The discharge is much affected by surrounding circumstances. The Neg. seems to discharge rather the easiest.

4420. *Relative discharge at n or o when equal* = 0·4.

U *pos.* Discharge by sparks at both places but more frequently at *n* than at *o*. U *Neg.*—then discharge once or twice at *o*—but principally at *n* and in a short negative brush; sparks were very few there—*n* has a continual advantage over *o*, perhaps by being the side towards the fire—but is some distance off, at least 10 feet. Discharge seems about equal: Neg. as readily as Pos.



4421. Made the intervals = 0·8. U Neg.: discharge at *n* as feeble neg. brush. U Pos.: discharge at *n* and *o* also—at *o* in feeble neg. brush, at *n* in Pos. brush with occasional spark. Neg. seems rather more facil than Pos. to discharge.

4422. *Transition from Spark to brush.*

At n, ball B *Pos.*—beneath and at 0·7 almost all sparks—at 0·73 many sparks, but a little brush—at 0·85 brushes and sparks—at 0·95 a few sparks—at 1·0 a frequent spark intermitting with brush—the brush dullish, straight down and direct, the spark very bright and angular—at 1·07, principally brush, but a spark now and then—this may be taken as the maximum limit.

4423. The sparks seemed to be all preceeded by a short brush as if the latter originated the former. This perhaps in greater or smaller degree a general result.

4424. *At n, ball* B *neg.* At and below 0·3, all Spark—at 0·32 a little brush now and then—at 0·43 sparks occasionally but much

OXYGEN. of the discharge by neg. brush—at 0·49 an occasional spark, but generally discharge by a miserable little brush—above 0·49 all brush.

4425. *At o, ball* A *Pos.* Up to and at 0·45 discharge by spark, with an occasional brush (neg.) at 0·45. At ·56 mostly in Neg. brush, but frequent spark; at 0·6 a spark or two—above 0·6 all brush (neg.) or indeed almost star or glow.

4426. *At o, large ball* A *Neg.* Pos. spark beneath and up to 0·82—spark jagged and bright—at 0·92 beginnings of brushes, running into sparks—at 1·05 many sparks—some brush and it poor as before—with 1·13 even, several sparks—at 1·23 had a spark or two, but then nearly all the discharge as poor brush.

4427. The state of the machine and size of the prime conductor, etc. material[ly] affect result as to whether it will be spark or brush, because of the quantity of electricity which is ready at any one time to pass.

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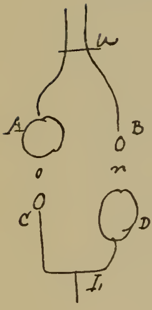
HYDROGEN. 4428. *Hydrogen in the receiver.*



4429. *Discharge compared with that in air, n* being 1 inch. U *or small ball* B *Pos.* When *p* or air interval was 0·16, all discharge was in air—at 0·20 a little discharge in the hydrogen—also at 0·22 some in hydrogen—at 0·23 discharge at both places *n* and *p*—with 0·28 discharge at both—at 0·31 a few discharges in air—also at 0·35—at 0·40 all discharge in the hydrogen.

4430. Made U or small ball B Neg.—at 0·22 all discharge in the air—at 0·24 all in hydrogen—at 0·23 generally in hydrogen but now and then in air. Here the Neg. seems to discharge more freely than the pos. by far.

4431. *Relative discharge at n or o when equal* = 0·4. U *Pos.* Discharge at both places, mostly at *n*. In both places it appeared as a pale gray, dilute or thin spark or sparky brush with little light. U *Neg.*—discharge at *n* and *o* but certainly *o* improved and is now most frequent—generally a brushy spark at both places, but occasionally a little bright red at *o* on the small ball C. It would seem as the small positive ball discharged a little the easiest, but not much difference.

4432. Made the intervals *n* and *o* = 0·8. U *pos.*—discharge almost always at *n* in Pos. brush, scarcely any signs at *o*. U Neg.—now most discharge at *o*, but some at *n*, reddish at *o* occasionally, not at *n*. Again, but now discharge more at *n*. Would seem as if small positive ball were a little the best, especially when inductric. HYDROGEN.

4433. *Transition from spark to brush.*

At n, small ball B *Pos.* The red spark beneath and up to 0·20—at 0·23 spark, but not above half of it was red and bright, the rest was of a gray colour and broad by comparison—at 0·25 mixed red and gray in one spark. At 0·4, still mixture of dull gray and bright red part in same spark—the dull gray being a state of transition to brush—at 0·48 very little red in the spark, i.e. very minute portion of red part; what was red was full and bright in its character—at 0·5 was the dull spark analogous to an exalted condition of brush—at greater distances the discharge was more brushy, but always very direct and single and snappy in sound, having the effects of sparks in discharging much at once. Continued to increase distance to 1·9 inches, but did not obtain the dense spark again, only the diffuse but still effective brush. These brushes are very different in character to what I obtained in other gases.

4434. *At n, small ball* B *Neg.* At very small distances, could not obtain a red spark, for enough could not accumulate to give the effect. At about 0·06 were red sparks—at 0·10 red but diminishing again in colour—at 0·14 spark not red but of the pale gray character, a dull diffuse spark, broad—and so continued up to 0·20, being quite across and straight as a spark but feeble in colour—at greater distances, the discharge still retained same character, but became more brushy—at 0·62 and upwards it was merely brush—up to 1·07 being often across.

4435. *At o, large ball* A *pos.* At intervals less than 0·3, the discharge was pale gray, brushy spark—then up to 0·5 the same, but with occasional tendency to red spark now and then—at greater distances, fine red sparks, occasionally mingled with brush, and at 1·25 now and then very fine sparks, red, etc.; also at 1·30, fine sparks sometimes from the quantity which passed.

4436. *At o—large ball* A *neg.* For distances less than 0·3 there was

HYDROGEN. red spark—after that blueness or gray crept in and also a brush at the small pos. ball—then brush only occurred, until rising to 0·75, a spark or two appeared again, perchance due to the strength of the accumulated Electricity—had occasional sparks even up to 1·15, but beyond that only brush discharge appeared.

4437. Thus the difference of Pos. and Neg. is apparent in the smaller intervals, the small Pos. giving sparks when the small Neg. could not.

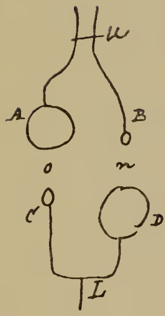
4438. A great difference appears in obtaining the red spark whether the Neg. large ball is the inductric or the inducteous. It is much better in the former case than in the latter, probably because then the circumstances cause more electricity to pass at once.

CARBONIC ACID GAS. Carbonic acid gas.

4439. *Discharge compared with that in air.*

Made *n* = 1 inch—U or small ball B Pos.—discharge constantly in air until up to 0·64, then sometimes in the C.A. Gas, occasionally by brush but mostly by spark—at 0·7–0·8—and even 1·0, spark often in air—at 1·2 spark in air—at 1·3 discharge by spark in the Carb. acid pretty constantly. Descended in the series—at 1·00 spark in both—down to 0·70 sparks in both—also at 0·6—at 0·5 all in air—at 0·55 a rare spark in the Carb. acid gas.

4440. *Made* U *or small ball* B *Neg.* At 0·3 all the discharge in air—at 0·35 some discharge in the C. Acid. At 0·4 the discharge principally in the C. Acid gas, a spark now and then in the air—at 0·45 a very rare spark in air—and above that the discharge was by brush always, in the Carb. acid gas.



This a very interesting result and shews how much better the small ball discharges in C.A. Gas when rendered Neg. inductrically than when rendered Pos. inductrically—difference very great—if free from error from charging of the glass, etc.

4441. *Relative discharge at n and o when equal* = 0·4. U *Pos.* Discharge almost all at *o*, but one or two sparks at *n*. U *Neg.*—discharge almost always at *n*, one or two sparks at *o*. Hence the Neg. discharge or spark predominates over the positive.

4442. Made *n* and *o* = 0·8. U *Pos.*—sparks at both intervals, but for the most part at *o*. Made U *Neg.*—now discharge all at *n*, sometimes as neg. brush, sometimes though not always as spark. Hence again the Neg. discharge most facil. CARBONIC ACID GAS.

4443. *Transition from spark to brush, etc.*

At n–small ball b *pos.* Was spark from smallest interval up to 0·82, then rarely pos. brush–up to 1·23 the spark very frequent indeed–above 1·23 or 1·3 generally Pos. brush. The brush poor as compared to that in air. *Small ball* b *Neg.*, then sparks up to 0·43–at 0·50 mostly spark but occasional Neg. brush–at 0·55 frequent sparks but some brush (neg.)–at 0·68 mostly neg. brush with an occasional spark–above 0·68 brush regularly (neg.). Hence Pos. longer sparks than Negative.

4444. *At o, large ball* A *Pos.* At very small distances and up to 0·15, the discharge hazy and bluish like dim spark, from the little electricity in it. Then spark bright came on and continued until interval was as great as 1·60–being from the small Neg. ball in an inducteous condition. This long spark continued up to 1·8, when the discharge was principally by brushes from the apparatus into the air. Could now and then obtain a brush inside at intervals *above* 1·60, but the tendency to form the spark was very striking. *Made large ball* A *Neg.*, and now obtained a bright spark from the smallest interval up to 1·10–above that I could not obtain either brush or spark–the charge went off into the air. Hence the tendency to form spark is very striking–and probably a very long pos. spark might be obtained in free space filled with C. Acid. But the formation of a Neg. spark of 1·8 and of a positive one only of 1·1 shews that Negative surface discharges most easily.

4445. Evidently want power to obtain the transition from Spark to brush in the last case, i.e. when large ball A is Neg. inductrically –and therefore small ball C pos. inducteously–most likely a very long spark.

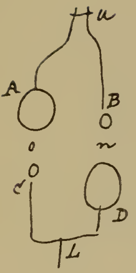
Nitrogen in the Jar. NITROGEN.

4446. *Discharge compared with that in air*, $n = 1$ inch.

U *or small ball* B *Pos.* At 0·29, all in Air–at 0·31 almost all in air but an occasional pos. brush at *n*–at 0·3 a very rare pos. brush at *n*–then pos. brushes at *n* increased in proportion up to 0·45, when they were more numerous than the discharges in air

NITROGEN. at *p*. At 0·6 however, an occasional discharge in the air—at 0·65 all discharge by Pos. brush at *n* in the nitrogen.

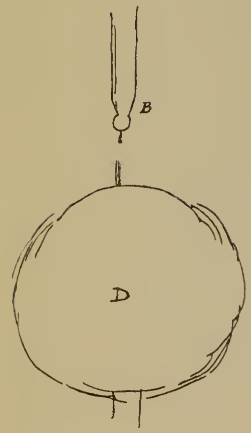
4447. *Made* U *or small ball* B *Neg*. At 0·31 all discharge in air at *p*—at 0·33 and 0·35 some discharge in the nitrogen by a little neg. brush—at 0·36 discharge at both places—0·37 a rare spark in air at *p*, nearly all by Neg. brush at *n* in nitrogen—so also at 0·38—at 0·40 all by Neg. brush at *n*.



4448. *Relative discharge at n and o when equal* = 0·4 *of inch*. U *Pos*.—discharge at both, most at *n*—generally by Pos. brush, but sometimes by sparks—the discharge at *o* sometimes by Neg. brush, but mostly by spark. U *Neg*.—discharge at both—nearly equal—at *o* always by pos. spark—at *n* generally by spark but sometimes by a dull feeble spark approaching to a brush. The tendency seems rather in favour of facil positive spark at *o*.

4449. *Made n and o* = 0·8 *of inch*—U *Pos*. All discharge at *n* as positive brush very near upon spark—doubtful whether once discharge at *o* by Neg. brush. U *Neg*. Discharge began always with Neg. brush at *n*, but soon came on and was most abundant with Pos. brush at *o*. This perhaps due to the effect of charging on the glass—the discharge was about equal in facility at *n* and *o*. Brush at both with feeble spark now and then at *o*. The interval *n* appears most favourable, but pos. discharge seems as facil as Neg.

Transition from spark to brush.



4450. *At n—ball* B (*small*) *pos*. Spark up to 0·30—at 0·33 an occasional brush—at 0·4 principally sparks but much brush—then sparks diminished and at 0·59 very seldom occurred—from 0·60 and upwards always brush (Pos.).

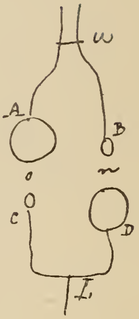
4451. *Made small ball* B *Neg*. From all distances up to 0·4 was Neg. spark—then a pale spark or beginning of brush appeared now and then—at 0·42 these more frequent—at 0·46 hardly one bright spark—all pale and thin. They consisted of a little brushy part at small *Neg. ball*—then a dark space—and last a dull straight line on the *large Pos*. At 0·5 an occasional small brightish spark occurred—then increased to 0·55—were occasional at 0·65—at 0·67 began to assume form of Neg. brush on B and glow on large ball D—but with the peculiar spark now and then—at 0·69 almost always Neg. brush or rather star and Pos. glow—at higher intervals

NITROGEN.

continued thus, i.e. with Neg. brush, the brush becoming better as the intervals were larger.

4452. The peculiar character of the discharge at 0·42, 0·46, etc. well worthy of notice.

4453. *At o, large ball* A *Pos.* Spark at all distances up to 0·52, and then began to appear that peculiar spark before mentioned—dull—divided and strait at bright part on both balls—at 0·68 these and the bright sparks nearly equal in number—at 0·77 fewer bright sparks—the pale sparks as before—the bright part always a purple weaker part in them and that near to the large pos. ball—being the reverse as to the place of the dull or dark part in the pale spark. An occasional bright spark at 1·0. Then the peculiar spark alone and very fine up to 1·55—then the part near the Pos. ball disappeared occasionally and the Negative brush alone resulted—at 1·65 and above the Neg. brush alone.



4454. Made U *or large ball* A *Neg.* Spark up to 0·40—at 0·41 nearly all spark but a little pos. brush—brush increased but sparks frequent at 0·88. Brush grew very tree like and sparky, and sparks occurred even at 1·72—at 2·00 Pos. brush.

COAL GAS.

Coal gas in the jar.

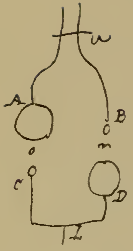
4455. *Discharge compared with that in air*, *n* = 1 *inch.*

U *or small ball* B *Pos.* With Air interval 0·2, all discharge at it—when 0·23, pos. brush discharge began at *n* in the coal gas—when *p* was 0·45, brush discharge pretty frequent in the gas at *n*—obtained there mingled discharges at *p* and *n* until air interval was 0·9, then had no more in the Air—all in the gas. Put interval at *p* back to 0·3, and still had some brush discharges in the gas. This great latitude probably due to the manner in which the glass charges—it is not unlikely that the character of the air or gass may influence this charge.

4456. U *or small ball* B *Neg.* At 0·2 all dischge. in air at *p*—at 0·21, Neg. brush discharge came on at *n*, and then the power of the air interval to dischge. ceased—at 0·27, first a dischge. in air, then Neg. brush came on in the gas, and could not again obtain discharge in the air.

4457. Made ball B Pos., and then had sparks in air and discharge in gas freely as before. Air interval 0·35 and ball B Pos., sparks

COAL GAS. in Air freely—but making ball B Neg., could then obtain no dischge. in Air, *all* in the gas at *n* by a small brush. Made ball B Pos. again—then plenty of dischge. in air. Hence the Neg. discharge must be easiest here.



4458. *Relative discharge at n or o when equal and* = 0·4.

U *Pos.*—discharge almost always at *o* by neg. spark—once or twice at *n*. *Made* U *Neg.*—now discharge almost always at *n* by Neg. spark—though sometimes the pale spark discharge occurred there. So Neg. discharge the most facil.

4459. *Made n and o* = 0·8 *of inch.* U *Pos.*: brushy discharges both at *n* and *o*, but much more at *o* by neg. brush than at *n*—U *Neg.*: discharge always at *n* by a neg. brush or stream—beginning with a spark or dull sonorous discharge but continuing as a quiet uniform brush.

4460. So here Neg. dischge. more facil than Pos.

Transition from spark to brush.

4461. *At n, small ball* B *Pos.* At certain intervals, the spark is bright, being sometimes red, sometimes green and sometimes both red and green at different parts. At other times, the spark is pale and dull but sudden and peculiar—partaking of a brushy character in its light, but sonorous, distinct and separate the one from the other—shall call this the dull spark. Below, at, and above 0·05, a bright spark—far brighter than when B Neg.—at 0·13 bright and pale sparks succeeded each other irregularly—at 0·22 some bright, the greater number pale sparks—at 0·3 a few bright, but almost all pale and diffuse, yet separate discharges and direct across—this continued up to 0·8 except that pale discharges spread out laterally and became brushy (pos.)—continued to enlarge the interval and the discharges became more and more brushy and paler, but at 1·42 even were still noisy and distinct as discharges—though now silent continuous pos. brush appeared frequently—at 1·55 some noisy discharges (pos.) dull: though the quiet brush frequent. The quiet brush reached across the interval. At 1·74 and even higher, were several noisy (pos.) discharges.

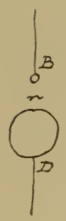
4462. *At n, small ball* B *Neg.* At all interval[s] less than 0·3 a constant spark—bright at the Neg. surface for about $\frac{1}{3}$ the interval and pale the rest of the way—it was very feeble at 0·05 compared to the Pos. spark—from 0·30 to 0·33, pale Neg. brush came on, and above 0·33 up to 2·00, all dischge. was as pale Neg. brush. COAL GAS.

4463. *At o, large ball* A *Pos.* From smallest interval to 0·3 a regular spark, being bright green at Neg. surface of small ball and pale at Pos. surface of large ball—from 0·3 up to 0·44 and 0·5, gradual variations, bright sparks occurring, several green in succession and then several red—then brush Neg. on small ball occurred occasionally, with bright sparks however up to 0·65, after which sparks rare and the brush contnd. up to 1·40. Then ceasing working and recommencing again, had noisy dull brushy spark discharges up to 1·70, but these would frequently give place to a constant neg. brush and that not alter till the working ceased.

4464. *At o, large ball* A *Neg.* Bright sparks up to 0·14, then a little palish and rather noisy and separate, as if not so easy as the Neg. sparks before at same distance—at 0·2 sparks, sometimes pale sometimes bright—at 0·25 quite the pale diffuse spark—at 0·3 singularly noisy and diffuse, yet straight across—at 0·47 generally the same but sometimes the narrow bright spark—at 0·68 continued the same except that bright sparks increasing. Up to 1·00 same, but the bright green and red sparks increasing in numbers. Bright green parts often occurred as scrubly brushes in dull discharges. These contnd. up to 1·90 and even higher.

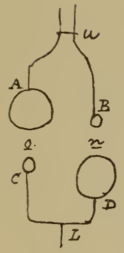
4465. To obtain good results, these experiments ought to be made in metallic vessels.

4466. *Summary of the previous experiments.*



		Air		Oxygen	
		discharge all			
	Intervals in air at p	in air, p	in gas, n	in air, p	in gas, n
Insulating power of gas	U or small ball B—*Pos.*	0·40	0·50	0·33	0·52
	” ” *Neg.*	0·28	0·33	0·27	0·30
	Mean Pos.	0·45		0·425	
	Mean Neg.	0·305		0·285	

4467.



		Air	Oxygen
Relative discharge at n or o in the gas.	n and o = 0·4 of inch U Pos.	nearly equal at n and o. sp.	nearly equal . . sp.
	n and o = 0·4 ” U Neg.	mostly at n. . . . Neg.	mostly at n—neg. br.
	n and o = 0·8 ” U Pos.	all at n. . . . . . Pos. br.	at n and o mostly br.
	n and o = 0·8 ” U Neg.	all at n. . . . . . Neg. br.	all at n. . neg. br.

4468.

		Air	Oxygen
		limits generally	limits generally
Change of spark to brush	small ball B pos. spark at n prior to	0·55. . . pos. sp. and br.	0·7 – 1·07 dull pos. br.
	” B Neg. ” n ”	0·30–0·32 . . neg. br.	0·3 – 0·49 neg. br.
	large ball A pos. ” o ”	0·40–0·42 . . neg. br.	0·45–0·60 neg. br.
	” A neg. ” o ”	0·75–0·90 . . pos. sp. and br.	0·82–1·23 dull pos. br.

Should be made in Metallic vessels.

Hydrogen	Carb. acid gas	Nitrogen	Coal gas
in air in gas 0·20 0·40 0·22 0·24 0·30 0·23	in air in gas 0·64 1·30 0·30 0·45 0·97 0·375	in air in gas 0·30 0·65 0·31 0·40 0·475 0·357	in air in gas 0·2 0·9 0·2 0·27 0·55 0·235
nearly equal—dull disch. most at *o*. mostly at *n*.—*p* br. mostly at *o*—*p* br.	nearly all at *o*. nearly all at *n*. mostly at *o*. all at *n*. *Neg*. decided advantage.	at both, most at *n* pos. equal. all at *n*—pos. br. most at *o*—pos. br. pos. a little the most facil.	nearly all at *o*. Neg. Sp. „ „ *n*. Neg. sp. most at *o* . Neg. br. all at *n* . . Neg. br. Neg. most facil.
limits 0·20—0·40—1·90, etc. 0·10—0·20—0·62, etc. All results peculiar and not comparable with the others.	limits 0·82—1·30 pos. br. 0·43—0·68 neg. br. 1·60—1·80 etc. neg. br. 1·10 and probably much higher—wanted room and power to get the longest pos. sparks with great ball A Neg.	limits 0·30—0·60 pos. br. 0·40—0·46—0·67 etc.? 0·52—1·00 ? 0·41—1·72 ? peculiar course and spark when ball B Neg.—so also when large Ball A Pos.	limits 0·13—0·8—1·42 0·30—0·33 neg. br. 0·30—0·65 neg. br. 0·14—1·00 and higher. dull spark, peculiar.

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4469. If a point were exactly midway and equally placed to two equal balls charged Pos. and Neg., what would it do? Theoretically the stem would do nothing, so what would a small conducting particle do? For charging of carrying particles.

4470. May not the cause of darkness in certain sparks near the Neg. ball, and of the black parts in discharges, be related to the differences of discharge by P. and N. surfaces; i.e. may not such sparks or discharges consist each of P. and N. discharges not quite the same in number or simultaneous?

4471. Is there ever more than one place in a spark black?

4472. A gaseous charged particle can dischge. to a solid or a fluid conductor—but should not be able to discharge to other gaseous uncharged particles—for it took its charge under that condition and the other particles are insulators.

4473. Gaseous charged particles cannot dischge. to uncharged solid or liquid insulators, as shell lac, sulphur, etc.

4474. Can gaseous charged particles discharge to solid or liquid insulators charged in the opposite manner—i.e. will a pos. glass rod be dischged. by a Neg. wind of air, etc.? A good expt. to make.

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4475. Expts. in correction of those of the 20th instant.

4476*. Arranged first an insulated conductor and two discharging balls so that the conductor and connected ball could be made *Pos.* or *neg.* at pleas.

Ball A or inductric ball 2 inches in diameter.

Ball B or inducteous ball 0·25 of inch in diameter.

4477. When *large ball* A *was made Pos. and inductric*—then spark alone occurred at discharge interval, when it was 0·48 or 0·49. Spark and brush occurred at 0·51. Brush alone at 0·52–0·57, etc.

4478. When *large ball* A *was made* NEG. *inductric*—then spark alone occurred with the interval up to 1·15. Spark and brush from 1·15 to above 1·55, and brush, to be regular, required at least 1·65.

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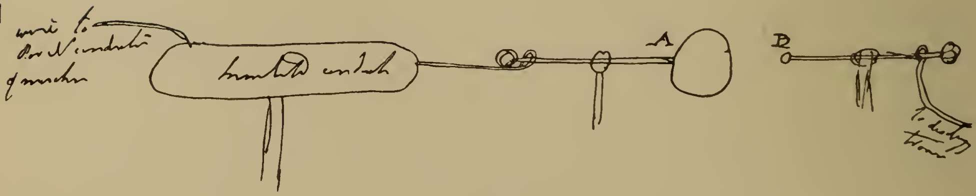
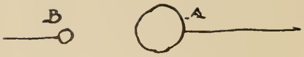
* [4476]



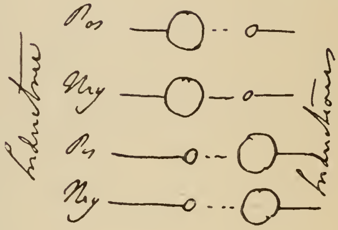
4479. Changed the balls A and B for each other. Now made *small ball* B *inductric* Pos. Spark up to 0·67. Spark and brush at 0·68–0·72. Brush alone 0·74—and above.



4480. Now made *small ball* B *inductric* NEG.—then spark up to 0·40—spark and brush at 0·42—noisy brush alone from 0·44 upwards.

4481. The results stand thus together:

Spark up to 0·49 . . . 0·52 brush beyond this. . .
,, ,, 1·15 . . . 1·65? ,, ,, . .
,, ,, 0·67 . . . 0·74 brush beyond this. . .
,, ,, 0·40 . . . 0·44 brush beyond this. . .



4482*. Now arranged the double system of balls. Made the intervals *n* and *o* = 0·9 of inch. *Balls* A *and* B *Pos. inductrically.* The discharge was all at *n*, mostly by *pos. brush*, once by *Pos. spark.*

4483. Made *balls* A *and* B *Negative.* Discharge was still all at *n*, by a constant Neg. brush.

4484. Made the intervals *n* and *o* = 0·6. Then A and B made *Pos. inductrically.* All discharge at *n* in a positive brush.

4485. Made A *and* B *Neg. inductrically.* Still all discharge was at *n* in *Neg. brush.*

4486. So discharge at P. or N. small ball certainly not much different—but the influence of inductric condition quite sufficient to overcome it, whatever it might be. Shews too that the small ball inductric surpassed the small ball inducteous.

4487. To counteract this inductric effect, made interval *n* = 0·79 and interval *o* only 0·58. Then when balls A and B were *inductric and Pos.*, the discharges were about equal at the two intervals. When on the other hand, with the same intervals, the balls A and B were inductric and *Neg.*, then there was discharge at both, but most at *n*—as if the *small Neg.* could dischge. a little easier than the *small Pos.*

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4488. Important to know whether two particles of air in opposite states, or differently charged in any degree, can associate together and yet not discharge or conduct to each other.

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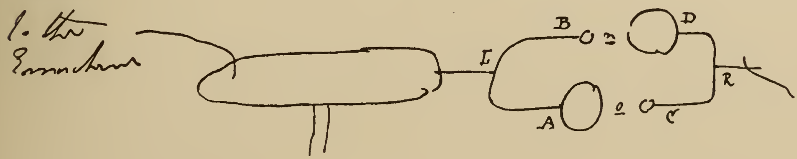
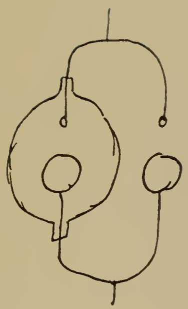
* [4482]



4489. Will a piece of shell lac charge in a current of electrified air—and if so, at what distance from the point, and to what degree relative to the charge of the air?

4490. Air may probably be highly charged in the middle of air less charged and so on, but what is the essential degree of difference between two contiguous particles necessary for insulation—and is it different for different gases?



4491. Make experiments on dischge., etc. in different gases as compared to air, using balls of the same size in both cases. The distance in gas may be fixed as before, whilst that in air is variable and used as the measure. Probably the Air ought to be in a vessel exactly similar to that containing the gas.

4492. Try discharge in vessel of gas, using the *unit* jar as the measure.

4493. Respecting my transverse speculations in series xiii. It would be important in relation to dielectrics to ascertain whether different dielectrics ought to produce different amounts of attraction—or whether the electrotonic condition is here the equalizer.

4494. Whether equal sized wires of copper and platina carrying equal quantities of Electricity would give the same lateral force.

4495. Discharge may be either from one particle to its neighbour, or back over itself. Consider this in connexion with combustion and also facilitation of much discharge by the commencement; and also the immense quantity of electricity in the atoms of matter as chemical affinity.

4496. Discharge of lateral simultaneous sparks; make them negative as well as positive.

4497. Hydrogen gives a red spark. Nitrogen a blue. Will a mixture give both red and blue like coal gas? If so, will illustrate specific gas action.

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4498. Made some expts. with 6 of Daniell's cells on conducting power conferred on water by acids, salts, etc. Found them very different and for a first approximation may arrange them into three classes.

Sulphuric, *Nitric*, *Oxalic* and *Phosphoric* acids gives much power.

Tartaric and *Citric* acids; *Potassa*, *Soda*—*Carbonates of potassa*, *soda* and *ammonia–Sulphate of soda–Nitre*–and *Bi carb. soda*–give less.

Acetic and *Boracic acids–Ammonia–Corr. Sublimate–Percyanide of Mercury–Iodine–Gum* and *sugar*–gave no sensible power tested by the Volta meter but would probably by the Galvanometer.

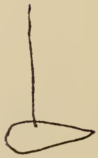
The results are useful general approximations.

1 MARCH 1838.

4499. As to charge of carrier balls when insulated and near to charged conductors ( ). Found that the carrier of 2 inches in diameter, when brought into the vicinity of the brass conductor of 18 inches long and $2\frac{1}{2}$ diameter, became charged in the *opposite state* when the conductor was charged pretty highly, but not otherwise except much time allowed, i.e. the conductor always required to be charged to a much higher degree than that acquired by the carrier.

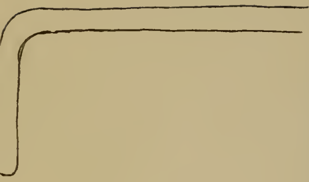
4500. Employed a small carrier of $\frac{1}{4}$ inch in diameter and found that it did not charge quicker or better than the large carrier, but that it did present the same phenomena. The effects were not so striking with it as the large one–not so ready. The small one requd. to be brought near and held some time there.

4501. With respect to the necessity or non necessity of a small ball receiving an actual charge, and not merely a polar one, before it can be attracted–in reference to the attraction of particles of dust, fixed an insulated small ball $\frac{1}{4}$ inch in diameter on a horizontal lever free to move, and then brought excited wax near enough to attract it to and fro. After a few seconds or a minute, examined the small ball, but could not find it had received an actual charge. Hence its assumption of polar charge seems quite sufficient here to account for the attraction, as it certainly is in the case of larger insulated conductors.



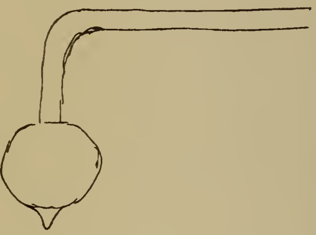
4502. When a piece of tin foil of this shape was suspended by a silk thread and brought near to a charged conductor, it was attracted and of course end ways, but it seemed a matter of indifference which end turned towards the conductor.

4503. A wire bent downwards had a drop of mercury suspended from its lower extremity, and this being electrified positively, gave



the glow. On approaching a ball or the hand towards it, the glow broke into a brush.

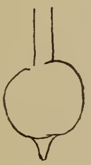
4504. On bringing a point towards it, the glow gradually contracted and brightened, and when point very near broke into short brush, and when still nearer into a spark. The changes seemed of the same nature as those with the ball or hand, except that as the point was finer, so the distance at which the glow changed into brush, etc. was smaller, and of course the brush itself the less distinct.



4505. Hung a drop of treacle on a ball ( ) and electrified it. When a point is brought towards it or towds. *other parts* of the conductor, the cone retracts because the charge is lessened, and therefore the adhesion of the treacle has the advantage. When very near the treacle is blown on one side from the force of the wind from the point.

4506. When a drop of treacle is electrified and so spun out into threads, these threads are blown off and dispersed from the action of several causes. First, the wind passing by the drop pulls it out, and as it elongates, the point being still the determg. place, the wind is along it and pulls it out the more. Again, it is whilst a thread a flexible conducting wire, and is therefore attracted towards that spot where the inducteous force is greatest, as a flexible metal wire or thread would be.

4507. If the fluid be a bad conductor, as oil of turpentine or wax, then the parts towds. the end of the cone or thread would tend to pass outwds. by their own electric state as compared with those *behind them*; i.e. they might be supposed to have a positive charge, and indeed so they have, for their making part of the conducting system, or their making part of the insulating current of wind or oil of turpentine, makes no real difference, since the inductric action in both cases of the charged particles is outward towds. the inducteous surfaces. But still the conducting power of water is so great, that for the little electricity a machine can give, it may be considered almost as good as a wire or thread of mercury.



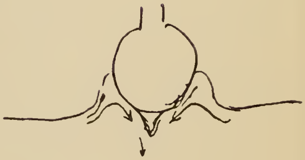
4508. A drop of mercury was suspended from a ball in a similar manner, and in the air this keeps its round shape. But in Oil of turpentine, opposed to a conducting surface, as the sides of the containing vessel (if of metal), it becomes very pointed and even particles of mercury were carried off by the currents of the oil of turpentine. The appearance of the mercury was just like that of the treacle in the air: the point was very fine but not so long.

4509. By bringing a point opposite to it, the mercury drop could be affected, as the treacle in the air, but not so readily, because of the density of the dielectric, etc. etc.

4510. Tried to obtain a glow on a treacled ball; this not easy because the high charge required for the glow drove off much treacle in threads, and when a drop by gravity, etc. formed at the bottom, there was generally some minute solid particle projecting and forming the apex and there the glow was—not over much of the ball. In fact, if fluid enough to move, it forms a cone in one place, where the mechanical forces predominate, as might indeed have been expected.

4511. A charged Leyden jar is not good to shew adhesion of oil of turpentine; the intensity is not high enough.

4512. A ball and rod on the machine or the hand is better. The *positive* ball lifts up much more than the *negative* ball. It is very difficult to tell which way the currents run, even when using threads of silk, for they cling about and are themselves affected. A drop of mercury, being pointed, served to shew that currents were as here figured and from the point of highest induction.



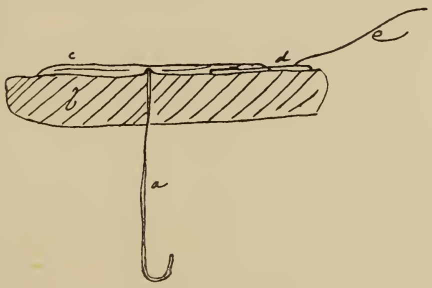
4513*. Tried to obtain Davy's elevation with water thus; *a* was a fine platina wire; *b* a plate of shell lac; *c* a portion of water on the lac just covering the exposed end of the wire *a*; *d* a piece of tin foil connected with a dischging. train.

4514. When *a* was connected with the Electrical machine in good action, no disturbance of the plane surface of the water over its termination could be observed. The conduction was very perfect, for no signs of electricity in the conductor could be observed.

4515. This failure might be due to the minute quantity of Electricity and its very low intensity. So charge[d] 2 Leyden jars and discharged them suddenly, a *wet thread* interposing between them and *a*. In this way, had for an instant, a quantity of electricity, and now obtained for the moment of discharge a wave over the termination of the wire.

4516. Must try this with the battery and a larger wire surface, and also with Voltaic Electricity.

* [4513]



4517*. Have been making expts. with aqueous solution and the voltaic battery for the Davy cones or elevations. Had a vessel of wax, with a zinc wire fitted through the bottom of about the size in the sketch next page[1]. The end of the zinc rose above the general level of the wax basin, but the wax was led up by a hot wire, so that only the end of the zinc was exposed, and that was well amalgamated. A ring of bibulous paper (cut at one place to lye close) was put on to the wax, extending from *a* to *b* all round, and then dilute Sulc. Acid was put in, and kept by this ring expanded so as to cause a lake or flood just covering the end of the zinc wire.

4518. Then using a voltaic battery of 100 pr. 4 inch plates, double coppers, Wollaston's construction, well charged—the zinc was made pos. and a platina plate dipped into the dilute S.A. Neg. Plenty of electricity passed, but though zinc at P. Pole, there was a little either of gas or steam from the heat set free, wax quickly melted there and covered the top of the zinc wire, and things were so disturbed (the gas at the Neg. pole helping) that I could not tell whether there was a Davy elevation over the wire or not. There was elevation now and then, but the rising gas might have caused it, and the result was doubtful.

4519. Used a similar arrangement, except that the wire was copper and the fluid Sul. copper solution, and the wire was made *Neg.* In this case there was no evolution of gas at the end of the copper wire, but copper was precipitated there and all was calm. There was also *no sensible elevation.* But on the other hand the copper deposited was ramose and divergent in all directions, and the smooth regular form of the wire end was instantly replaced by a tuft extending laterally in all directions: and further, but little of the electricity which the battery could supply passed. Whereas in the mercury experiments of Davy, there was not this deformation and the current of electricity could all pass freely.

4520. Then poured out the sul. copper solution and used Mercury in the same vessel, and found that the 100 pr. of plates, though the spark shewed that more electricity was passing, could not

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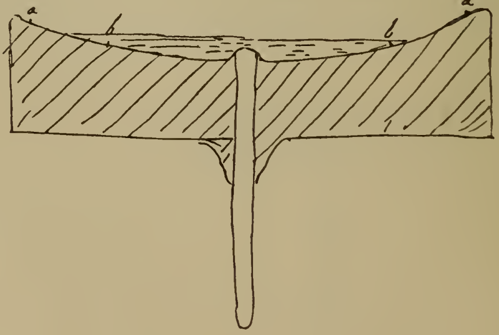
[1] Sketch is below: reduced to $\frac{3}{4}$ scale.

* [4517]



produce the elevations in it. There were not sufficient for the purpose.

4521. Davy used I think 500 or 600 or more. Wrote to Pepys to ask him if he remembers how many at the London Institution was used.

4522. Had a similar arrangement made with a platina wire, the wire being only $\frac{1}{50}$ of an inch in diameter—and used distilled water. On making the contact I could obtain a little elevation, but bubbles of gas were rising and probably produced the effect. Could not trust the result.

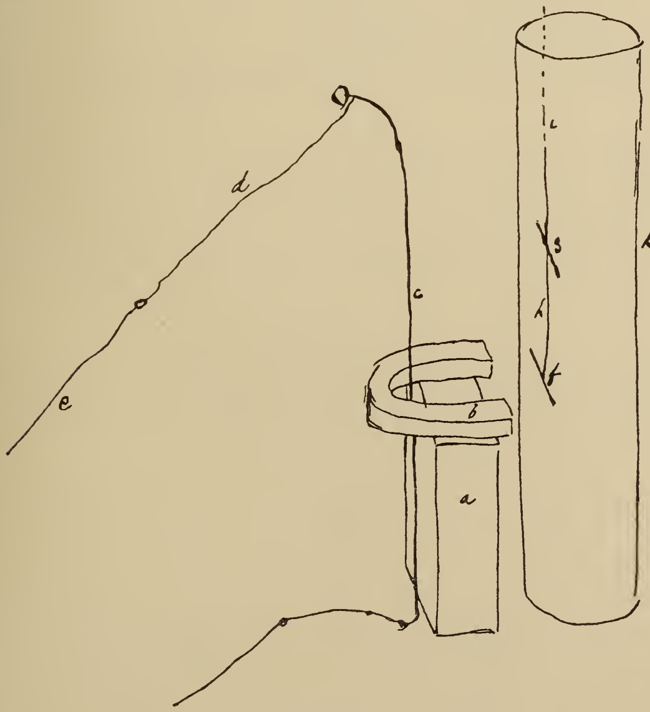
4523. I do not think Voltaic battery actions will do with decomposable substances. I must try the Leyden battery and water.

8 MARCH 1838.

4524. Continued the last experiment using the Electrical machine and large battery, which were in good action. Used the fine wire apparatus (4513) and discharged the battery through a thread. Obtained a little conical elevation each time, but there was also a little gas set free, and as that alone would produce a part of the effect, cannot be quite sure of any of it. I think part of the cone effect was due to the stream action, i.e. is like Davy's elevations, but it is very difficult to make the experiment unexceptionably.

4525*. Have made many experiments to detect transverse effects of convection. First, as to how to make a straight discharge

* [4525]



evident, it being only for a moment. *a*, a block of wood supporting a soft iron horse shoe; *b–c*, a thick wire, fixed at the bottom, attached at top to a wet thread *d* and a wire *e* through which the retarded discharge of the battery could be made. When such a discharge passed, *b* ought to become a momentary magnet. *f* and *g*, two magnetized needle[s] upon a fixed slight stem *h*, forming a needle nearly astatic, suspended in a glass jar by a single silk worm thread, and so arranged that *f* should be nearest to the horse shoe *b*, and therefore easily affected if the latter became a magnet.

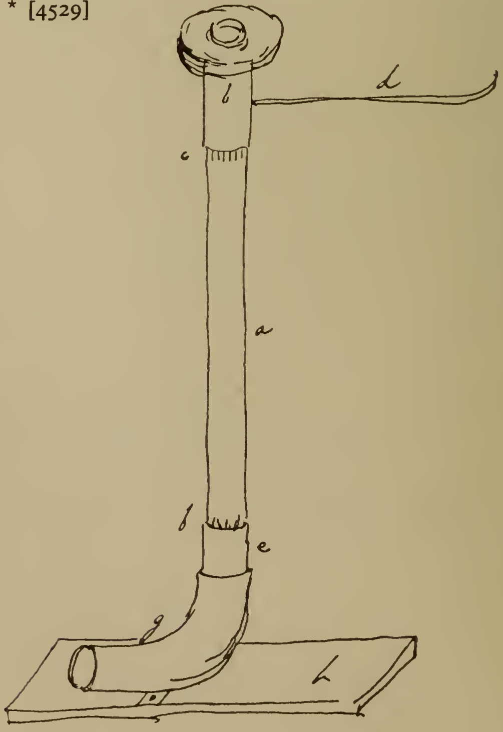
4526. When the Shock of the battery was passed through *c* unretarded by the interposed wet string, then there was affection of the astatic needle, but principally and for aught I could tell entirely, by an alteration of the Magnetism of the needles, due to the shock current down the wire.

4527. On making the discharge through the interposed wet thread, there was an effect on the needle–apparently not due to this effect, for it was not permanent–but the consequence of the soft iron becoming a magnet for the moment.

4528. A smaller horse shoe of soft iron apprd. to act as well but not better.

4529*. Now have had a tube convection apparatus made to replace the discharge wire *c*. *a*, a varnished glass tube 12 inches long and $\frac{7}{8}$ in diameter; then *b* a brass tube topped by an ebony

* [4529]



ring to prevent loss by diffusion; *c*, needle points fixed on a wire springing into *b* and projecting within the glass tube; *d*, a connecting wire for the battery; *e*, a brass tube containing needle points *f* as before; *g*, another brass tube open at the end so that air might be freely blown through the apparatus and out above; *h*, a board serving as a base.

4530. On charging the battery and connecting *d* with it, whilst *e*, *g* was connected with the outside, there was *no discharge from the one set of points to the other*. Nor was there any discharge when air was blown through.

4531. Must try by blowing air down from the charged part, but do not expect discharge by convection. For the dielectric cannot move, i.e. the glass is a fixture; its particles become polar as the rest, and after a few moments *charged*, and then, as they cannot move, they act like charged fixed conducting matter, and the fact probably is, that the points are not in a charged state, but some part of the glass beyond them.

4532. By large machine brought glow on to a ball an inch in diameter. On approaching the hand or another ball, this glow tended to break into brush, but working machine harder, kept it as glow: then, moving the hand or the ball from side to side, the glow (which was contracted and compressed by the approach of the hand or ball) moved also, following the motion of the former.

4533. A point brought towards the glow would at 12 or 14 inches make it break into brush—nearer still, the glow was reproduced, probably by *discharge* of wind or air passing from the point to the ball. This latter glow was very moveable, following the point about in all directions.

4534. When glow was on the ball, brought a varnished tube near to it sideways and blew through the tube at the glow. The latter was evidently displaced, being *blown away* as it were, and on ceasing to blow returning to its first place. The glass tube remaining steady in the same place all the time.

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4535. As to attraction of a perfect non conductor by a charged body. Suspended a slender stick of shell lac with a little knob at the end horizontally by a delicate torsion suspension, and then brought an excited shell lac rod near the knob. It was of course easy to see whether there was attraction or repulsion.

4536. If the excited rod was powerfully charged and brought near to the knob, there was communication of electricity, and the knob becoming also Negative, was repelled.

4537. If the excited rod was moderately charged so as not to effect this communication, then there was no sensible attraction or repulsion at distances which would have shewn it with conductors powerfully [charged]—but still nearer there was attraction.

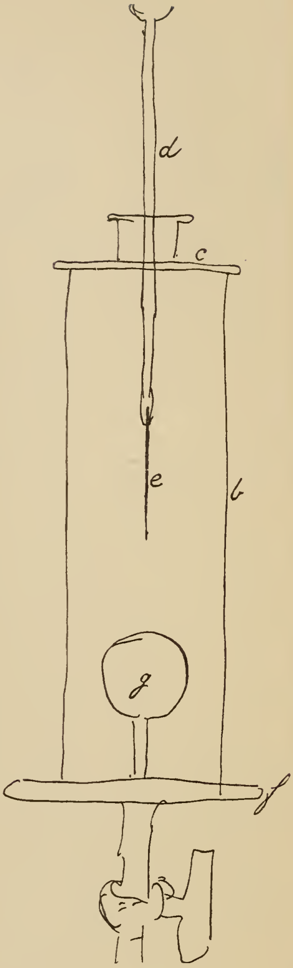
4538. In these cases of attraction, the knob attracted was examd. as to its state by bringing it near to the electrified ball of my Coulomb's Electrometer—a far more delicate test than the gold leaf electrometer, though made very small.

4539. If the excited rod was held at the attracting distance and kept there for a while, the attraction became stronger and stronger, and in all such cases it was found that the knob had acquired an *opposite* or a *pos. state*, having doubtless discharged Neg. Electricity to the air, as a conducting carrier ball has been seen to do before it. And as the attraction came on and increased gradually, it might be concluded that it was always due to this assumption of the opposite state.

4540. But if excited rod held near enough for a moment only, attraction appears and that on either side or at different parts in quick succession; and in such cases, on examining the knob afterwds., I could not make out it had assumed a permanently excited state; so that it appears as if it had been attracted, and yet not charged.

4541. This is possible with bodies, which like shell lac, sulphur, etc. have greater inductive capacity than air. For such a piece of matter, being in the course of inductive action existing between the Inductric and inducteous surfaces determines more induction through it than through an equal space elsewhere; and that will cause the forces to make it approach the inductric body, for the nearer it is to it, the greater its angular dimension in relation to the center of action, the more easy will the induction be in that direction. It will have an effect equivalent in kind though not in degree to an insulated conductor, which, becoming polar, is attracted etc. without really receiving a positive or general charge; the polarity of the conductor and the greater capacity of the insulator each in its way facilitating the induction through or across them, i.e. each making the action between the inductric and inducteous surfaces greater in their course than elsewhere.

4542. In reference to lateral action of convection discharge, I have had a little apparatus made in which more side room is given for the relation and motion of the dielectric air. The sketch is about full size[1], for if successful it had to go within the curve of a soft iron horse-shoe. *b*, a glass cylinder well varnished; *c*, a brass plate carrying a sliding wire *d* terminated below by a fine needle *e*; *f*, another brass plate carrying a rod and ball *g*.



4543. The bottom plate *f* was quite uninsulated; the large Leyden battery charged and then discharged to *d* by a wet thread. Unless the charge of the battery was pretty high, no discharge took place within the cylinder, or very little. When sufficiently high, dischge. occurred as a streaming spark from the point to the ball and then suddenly ceased again.

4544. No wind discharge took place within the jar. So that it will not do for convection form of experiments.

4545. Charged the battery till divergence of the electrometer was about 10°; dischge. would not occur through the jar—at 20° no dischge.—at 30° no dischge.—at 40° none, at 50° dischge. and the whole fell to 5°. So that though 10°, 20° or 30° could not cause dischge., when once begun, they and much less degrees could *continue it*, shewing the favouring power of discharge for itself.

4546. Now removed the battery and put the prime conductor in direct communication with the wire *d*. Could not obtain the wind discharge; was a brush or a spark discharge. But on removing the glass cylinder, then obtained the wind discharge, and the distance could be very much diminished before that ceased and spark came on.

15 MARCH.

4547. Repeated the expents. of (4340, 4343) with Air, oxygen, Carbonic acid, and Olefiant gas in the Varnished vessel. The varnished vessel was the same as that used before.

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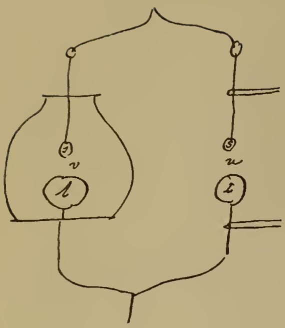
[1] Reduced to half scale.



4548. The balls *s* and S were each 0·9 of an inch in diameter. The balls *l* and L each 2 inches in diameter. The interval *v* was constant and was 0·62 of an inch.

4549.

			discharge all at *u* with *u* = or less		discharge all at *v* with *u* = or more	
Air	*s* and S	Pos.	0·59 of inch	·11	0·7 of inch	
	„	Neg.	0·64 „	·06	0·7 of inch	
Oxygen	„	Pos.	0·63 „	·17	0·8 „	
	„	Neg.	0·65 „	·07	0·72 „	
Carb. acid	„	Pos.	0·70 „	·47	1·24 „	
	„	Neg.	0·70 „	·20	0·90 „	
Olefiant gas	„	Pos.	0·88 „	·22	1·10 „	bright spark
	„	Neg.	1·00 „	·12	1·12 „	pale spark.

4550. Difference when small balls made neg. and pos. (see 4351).

	when pos.	when Neg.
In air	·11	·06
oxygen	·17	·07
Carb. acid	·47	·20
Oleft. gas	·22	·12

4551. Taking the mean air distance as representing the restrang. power, then it comes out as below (see 4353).

	Pos.	Neg.
Air	0·645	0·670
Oxygen	0·715	0·675
Carb. acid	0·970	0·800
Oleft. gas	0·99	1·060

4552. Endeavoured to obtain a luminous discharge between two electrics, one negative and the other Pos. This not so easy. The excited glass of a cylinder machine gives a good brush to a knuckle, and the excited cylinder of shell lac will also give a feebly luminous discharge to the knuckle, but these will scarcely give a discharge one to another. I doubt whether I once obtained such a luminous discharge distinctly—both separate retaining their electrified states.

4553. If the knuckle or approached body could not discharge the electricity as it received it, being conducters, the brush would not occur. At least that seems to be the case. In these cases the Inductric surface is a large one and the inducteous surface comparitively small.

4554. Endeavd. to repeat De la Rive's Expt. on the effect of heat on a current. Bib. Univ., 1837, vii, 388.

4555. The voltaic arrangement was four pair of zinc and Platina plates (the former amalgamated) in dil. S.A. of 1 acid, 20 water. The plates were about 2 inches by ½ an inch in size. The Galvanometer was with two needles and delicate. The Electrodes were platina, about 2 inches by half an inch, and the fluid dilute Sulc. Acid, arranged as described by De la Rive.

4556. With the four pr. plates, the Galvanometer was too much affected. With 2 pr. of plates, the constant deflection was about 10°. Then heating *either* the P. or the N. electrode increased the def[l]ection to 20° or 30°. At first, heating the Neg. electrode seemed to produce most effect, but after a while heating the Pos. seemed as effective. Heating both produced more effect than heating one.

4557. Heating a part of the platina distant from the liquid produced no effect. Heating the surface of the liquid by a blow pipe in the middle part produced no effect. Heating the surface at the platina or the platina then produced much effect.

4558. Heating the Neg. seemed to be a little more powerful than heating the Pos.

4559. On remg. the couples causing the current, then heating the plates of platina as before did nothing.

4560. Hence the current is facilitated, but I do *not find* the difference spoken of by M. de la Rive.

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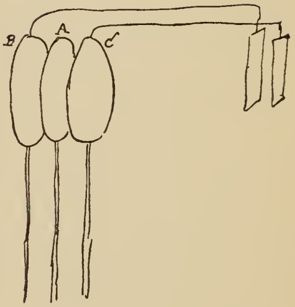

4561. Have had three brass plates made and insulated on varnished glass stems (see 1252 of Series xi). Arranged them about an inch apart, connected the two outer by 2 wires with 2 insulated leaves of gold. Electrified the middle one and uninsulated the two outer plates.

4562. Then brought a plate of shell lac, suspended by long white silk threads, between the plates; found the leaves of gold were affected because of its own electrified state. Discharged it perfectly by wiping with a finger and silk handkf. and breathing.

4563. Then brought the shell lac plate between A and C, and the gold leaves were attracted towards each other. Touched the plates B and C, so that the gold leaves hung parallel, then insulated B and C, and took out the shell lac; immediately the Gold leaves attracted each other, though nearly 2 inches apart, and touched. On again introducing the shell lac between A and either of the plates, the gold leaves were attracted, etc. as before.

4564. Made the distance between the gold leaves so much that putting in or taking out the shell lac plate cause convergence but did not make them touch each other. Then put the shell lac into one interval, uninsulated, and insulated the plates B and C–took out the shell lac and the gold leaves shewed attraction and approached–put the shell lac into the other interval and this attraction was increased, so that the two leaves came together and discharged each other.

4565. In all these cases of discharge between the gold leaves, the plates were left as if they had been perfectly uninsulated; i.e. there was no excess of P. or N. power.

4566. All these effects had been anticipated–they are simple consequences of the specific inductive capacity of air and shell lac, and giving a form under which the results are very evident. It is also one under which they are very delicate, and will probably apply to the examination of gases, etc. etc., and to the differences of thick and thin plates.

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4567. The molecules of insulators are probably themselves conductors throughout, but insulated from each other. Else not polarize in any direction at pleasure.

4568. Then the particles can either polarize under induction as conductors do–or bodily as they also do by communication.

4569. In that case, electricity will in the Leyden Jar, etc., be on the external layer of insulating particles and not on the conductor.

4570. Hence may polarize in different direction–though perhaps shew an aptness in crystals to polarize in one direction better than another.

4571. Hence the molecules of a body are in different relations to the elements. The molecules polarize or conduct as wholes, but the elements only as parts of wholes unless they are the immediate molecules. Thus in oxygen and lead, etc. etc. the particles of oxygen or lead polarize as wholes, but in oxide of lead, not, for there (by theory only) the wholes each consist of several particles of oxygen and lead in perfect conducting relation to each other.

4572. Must follow out these considerations into cases of weak affinity, as solutions; and other cases, if there be such, where particles of one body may be supposed to be in relation to several particles of other bodies.

4573. May perhaps bear upon the way in which salts, acids, etc. give conducting power to water.

4574. Assuming that the molecules conduct throughout their mass and that the outer layer of those in dielectrics charge bodily, then must work out the point of definite amount. Intensity must be excessive between particles so near to each other—but varying with the distance, must carry up this and the corresponding quantity to that which is indicated in electrolyzation and relate the two.

4575. Fuzed sulphur or lac in glass or metal or other such cases—are probably the connecting links between excitation by chem. affinity and friction. Are evidently fit to be half way between.

4576. Must examine them closely as to the kind of electricity—extend them, and prove either their relation or non relation to the two.

4577. The difference of Pos. and Neg. facility of discharge at large and small surfaces. Consider this in relation to Voltaic excitement and current. Will it not account for arrangements of one fluid and one metal, the latter being large at one end and small at the other?

4578*. Try this arrangement. I think it ought to give a current. Also try every other one turned round.

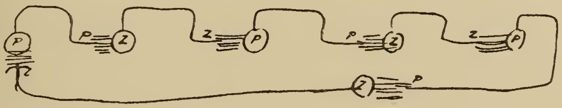
4579. In reference to the consideration of the molecules of a dielectric as always conducting particles, and to the intensity of inductive action between two neighbouring particles, consider the relation of Specific inductive capacity and that intensity; see 4279.

4580. Also relation of form, size and number of particles.

4581. Query the physical difference (if any) between Oxygen and Hydrogen when free and when combined together.

4582. Pointed form of leaves in nature may be effective in bringing up a discharge of electricity of very low intensity to a sufficient intensity to decompose or electrolyze; see 105, 414, 555.

* [4578]



4583. Have continued experiments with the *Differential Inductometer* ( ).

4584. One inducteous plate does very well. Thus electrizing plate A; connecting plate B with a gold leaf electrometer and removing plate C; on putting shell lac between A and B, the gold leaf of the latter diverged—according to circumstances, Pos. or Neg.

4585. As the plates A and B were separated, the indications were less energetic, and as approximated they were more delicate. But then I was using the same plate of shell lac and not increasing its thickness with the distance. The difference was not very great with a separation extending from 1¼ to 2¼ or more times the thickness of the shell lac.

4586. To verify the conclusions, made A neg., and the gold leaves were discharged, air being between A and B. Afterwards introduced the plate of shell lac; the gold leaves immediately opened, and by removing the connecting wire were left insulated, before the shell lac was removed. Then on examination found them *Neg.* according to my expectation. For as introducing the shell lac made plate B more pos. towds. plate A than before, so the further part of the arrangement, i.e. the gold leaves, ought to become Neg. to an amount equal to the fresh Pos. effect induced on B.

4587. Used a thin plate of shell lac about 0·3 of an inch in thickness. When the interval between A and B was 1½ inches, the introduction of this plate produced an effect. So that thin plates of bodies may be used and examined. But as the interval was lessened, the effect of the shell lac became more and more striking, until the whole interval was filled at the alternate examinations either with air or with shell lac. This was according to my expectation.

4588. Now used the two inducteous plates B and C for the purpose of trying the different circumstances affecting the sensibility of the instrument. Used of course the separate gold leaves, i.e. one to each inducteous plate, but hanging parallel to each other.

4589. Bringing the gold leaves nearer made the instrument much more delicate.

4590. Bringing the three plates nearer also made the instrument more delicate. The improvement was greater than before.

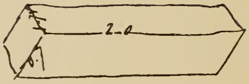
4591. Now used the two inducteous plates B and C, but connected each with a separate gold leaf electrometer having two leaves. On placing the plates rather far apart, as for instance 1½ inches, and introducing the lac, the electrometer of the plate inducteous through the lac diverged considerably, but the other only a little.

4592. This was because much of the induction of the middle plate A was towards external objects from the edge of that plate, so that part of the force gathered together by the lac upon B, for instance, was not taken from plate C but rather from those bodies towards which the edges of the plate had acted by induction. And on bringing the plates B and C nearer to A so that this external induction should be lessened, then both Electrometers were affected and diverged with contrary electricities, in accordance with the determination already given (   ).

4593. Tried a piece of a dielectric: thus a piece of sulphur not[1] was put between the plates; it did not hide more than ⅓ of the surface of one plate from the other: but still it produced a striking effect. The same with a piece of shell lac. But it is far better that the dielectric under examination should occupy all the space between the plates, both in extent and thickness and even if convenient project at the edges.

4594. I think the two leaf apparatus is better than separate Electrometers.

4595. Now used a piece of calcareous spar as the dielectric, a rhomboid 0·7 inch thick and from 1¾ to 2 inches in the sides. There were 3 or 4 cross layers and several fissures going from face to face. So that it was not a good piece.



4596. In the first place, warm or even cold, it did not discharge a charged gold leaf electrometer but insulated very well.

4597. In the next place, being excited by friction, it held its charge for a long time, an hour or more, so that it must be a good insulator.

4598. It was now slung by white silk thread; perfectly discharged by finger wiping, and then tried in the *differential Inductometer*.

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[1] ? rod.

It produced very striking effects, indicating a *high inductive capacity*. On removing it from the instrument, it was found free from all charge.

4599. Repeating this several times with all precautions, the effect was the same. Hence this a good substance to work with as to relation of inductive lines of force to the crystalline axis of the body.

4600. Now experimented on the effect produced in the instrument if the dielectric used is introduced, either in an excited state, or becomes charged by contact with plate A, or by other circumstances during the investigation.

4601. The piece of dielectric (shell lac, sulphur or spar) which is under examination, being suspended by white silk, was first examined as to its charged state. This is easily done by a gold leaf electrometer—but it is much better to diverge the leaves first and then observe whether the approach of the dielectric affects this divergence, increasing or diminishing it; than to bring the dielectric near the collapsed instrument. Degrees of excitement that will not sensibly open the leaves, in the latter case, will abundantly affect them if they be previously diverged.

4602. The charge, if any, may be removed by breathing and wiping, as formerly described.

4603. A plate of shell lac was excited a little. The three plates A, B and C of the differential inductometer were all *uncharged*. The plates B and C had each the single leaves in relation to each other. On introducing the lac, no effect was visible at the gold leaves. But when plate A was charged, all the effects due to difference of specific inductive force came out. Yet on discharging plate A, again no effect was produced by introducing the shell lac, still in its excited state.

4604. On exciting the plate of lac more strongly, and having A, B and C uncharged—on introducing the lac into either interval, the gold leaves slightly repelled each other, as should be the case: and then if whilst lac in one interval the plates B and C be uninsulated, so as to bring the gold leaves parallel; on taking out the lac they attract each other, or putting it into the other interval, still stronger attraction ensues. The same effect occurs if the middle plate A be removed and the lac be swayed to and fro between B and C. As it leaves one to approach the other, the intensity of their induced states change and of course the attached gold leaves are affected and attracted one by the other. Even if the lac is approached on the outside of the plates the same thing happens.

4605. But this requires a comparitively strong charge of the lac, one very easily detected, easily removed and vastly greater than the small degree of charge which may occasionally be taken on in the course of an experiment; and for any moderate charge of the dielectric, the immediate effect is so small compared to that due to specific inductive capacity, that no chance of confusion need occur.

4606. Then the Calc. spar was purposely electrified a little (very sensibly to the gold leaf electrometer) and then introduced between the plates of the uncharged differential inductometer. It did not sensibly cause motions in the gold leaves when they were only ½ an inch apart, but on electrifying plate A, the leaves were powerfully affected when even 1½ inches apart. Discharging A, the effect was then as little as before.

4607. The direct action of the excited dielectric in this case could not have been $\frac{1}{20}$ part of the effect produced by the difference of specific inductive action.

4608. Tried the specific inductive capacity of a plate of Borate of lead in the apparatus; it gave strong effects, indicating a high capacity.

4609. I lined the two faces of the Calcareous spar with tin foil to have a large surface of contact, but it then insulated as well as before.

5 APRIL 1838.

4610. Examined the piece of calc. spar; find it conducts readily. Trace this however to the fissures going through from one side to the other; the water of the paste had got into them. Stripped off the tin foil and found these lines of fissures conducted. But in other directions the calcareous spar insulated as well as before (   ).

4611. I must make a small differential inductometer; and use perhaps balls instead of plates. The carrier ball of the Coulomb electrometer being the inducteous surface. It is evident from 4233 that it will do, and in this way, and by connecting the inductric ball with a charged jar, so as to sustain its state, may probably obtain accurate measures of force.

4612. The large differential Inductometer is a good instrument to shew the relation of distance to charge—by moving one plate or the other.

4613. Might measure Specific inductive capacity by Harris' electrical balance, interposing equal plates of different dielectrics between the two attracting surfaces.

4614. The high Spec. Inductive capacity of glass is of great consequence in the Leyden Jar. So also that of lac or resin in the Electrophorus, etc. etc.

4615. Must consider what effect a difference of Specific inductive capacity may have on the polarization or on the polarized state of the particles of the dielectric. Must consider the relation of polarity and capacity and ascertain, if I can, on what capacity depends.

4616. Must state distinctly that in normal condition the particles are *not* polarized. They become polarized only under inductive action, just as so many insulated *conductors* would do. They are in fact so many insulated conductors, acting upon and through each other.

4617. Certainly crystalline particles ought to shew differences in different directions, but we shall see what the experiments will do.

4618. The solidification of an electrolyte prevents the current passing. This seems a very natural effect if we consider that the whole molecules are *fixed*; for the internal commotion cannot take place. If a particle of water be polarized and then the oxygens and hydrogens travel on to the neighbouring particles, in the fluid state they can turn round and again polarize, but in the solid state they are placed and *fixed* in the wrong direction.

4619. When decomposition happens in a fluid electrolyte, it is not all the particles in the same sectional plane which part with and transfer their electrified particles at once; probably the discharge force for that plane is at the moment summed up on one or two particles which decompose and restore the balance, just as in the case of spark disruptive discharge: for as those which have just discharged must be less favourably circumstanced than others, there must be some which are most favourably disposed, and will, by giving way first, lower the tension and produce discharge.

4620. Must try polarized light across a crystalline dielectric under charge. Good reason perhaps now evident why a non crystalline dielectric should shew no effects.

4621. In excitement by friction, consider the effect of coating the inner surface of the glass rod, and allowing for the time induction through it.

4622. Want terms to express certain relations and conditions of matter and its particles. Thus when a particle is said to be charged or electrified, we understand what it means; and so also when uncharged or unelectrified. But how are we to express the *Polar* state; is it a *charged* state, or what are we to call it?

4623. Must put together what relates to the ascertaining of the lines of equal inductive force round a charged body. The wire end—ascertain this pretty well for its own particular case, 2715, 9, 20, 21, 3771.

4624. Consider the state of two particles of a dielectric at opposite ends of a *polarized* conductor—and then exact relation to each other.

17 MAY 1838.

4625. Graham has lent me Thilorier's Carb. acid apparatus and I have been experimenting with it in cooling metals and ascertaining their relation to Magnetism. The metals were in pieces, kept a while in the mixture of Ether and C.A. with solid C.A. in it, and moved either by platina wires or by wooden tongs. The temperature according to Thilorier would be about 112° below 0° of Fahrenheit.

4626. Antimony
Arsenic
Bismuth
Cadmium
Chromium
Cobalt
Copper
Gold
Lead
Palladium
Platinum
Rhodium
Silver
Tin
Zinc

These gave no deflection by a double astatic needle that was exceedingly sensible to the smallest particle of Iron or nickel.

Great care was taken to avoid the effect of a downward current of air at the side of the cooled metal.

4627. *Iron* and *Nickel* seemed as magnetic at the lowest degree as at common temperatures. *Carbon* (dense) from a gas retort was not rendered magnetic.

4628. Native *Iridium* and *Osmium*—and crystals of *Titanium*—were a little magnetic at common temperature, I believe from the presence of a little iron. They were not more so when cooled to −112°, so that the metals Iridium, Osmium and Titanium do not seem magnetisable at that temperature.

4629. Metallic Manganese from Mr Everitt. Slightly magnetic and polar at common temperatures—not more so when cooled—must now examine its purity.

4630. Then tried various metallic combinations, for which see the next page[1]. Thus—

4631. Hæmatite
Crystd. Green Vitriol
Dry Green vitriol
} did not acquire any magnetic power.

4632. Galena
Realgar
Orpiment
Dense Native Cinnaber
Sulphuret of silver
,, ,, copper
,, ,, Tin
,, ,, Bismuth
,, ,, Antimony
} Gave no signs of Magnetism.

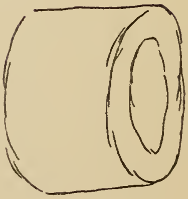
4633. Chloride of Silver
,, ,, lead
Iodide of Mercury
} fuzed into lumps. Gave no signs of magnetic force.

4634. Fuzed protoxide of lead
,, ,, Antimony
,, ,, bismuth
,, White Arsenic
Native oxide of tin
,, ,, Manganese
} No signs of Magnetic force.

4635. All the facts were negative. This is important as a correction respecting Cobalt and probably Manganese.

5 JUNE 1838.

4636. Experimented with the view of finding some action on insulating dielectrics analagous to the currents by induction produced in conducting bodies.



4637. A ring of iron in form of a cylinder about 2 inches high, 2 inches external diameter and $1\frac{1}{4}$ inch internal diameter had 80 feet of silked copper wire rolled onto it as in the figure*. It may be called ring I. Another ring, of wood, of equal size, had as

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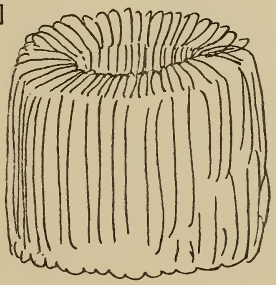
[1] Immediately below.

* [4637]



much as 162 feet of covered wire rolled in a similar way on to it, and may be called ring W.

4638*. Cores of lead, shell lac and sulphur were cast, being cylinders about 2½ inches long and 1 inch thick, which could be placed in these rings at pleasure. The follng. arrangement was made. I the iron ring; L a lead core, touched at the ends by wires going away to a delicate galvanometer G, of which the needle moved in the direction of the dotted line when the current was as indicated by the arrow R. V is a voltaic battery of 10 prs. of 4 inch plates, Wollaston's double coppers, well excited, and P is the wire from the Pos. end; N the wire from the Neg. end.

4639. When contact was made at N A and B P, at the moment of completion the needle moved towards the dotted position. When contact was broken it moved the reverse way.

When the lead core was in a wrapping of paper, to make insulation more perfect, the effect was the same.

4640. When a mere copper wire was used in place of the lead core, the effect was the same.

4641. When the wooden ring W was used, the same effect was produced but in a smaller degree.

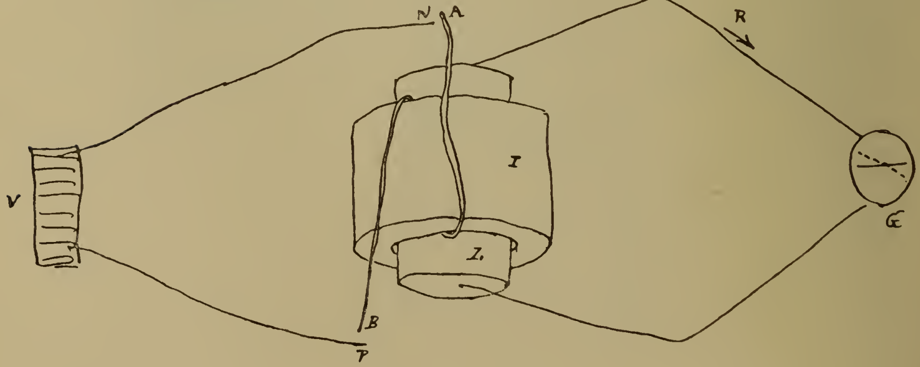
4642. Now used a core of shell lac, having small discs of tin foil pasted on the ends, and to my surprize obtained effects on making and breaking contact, smaller in degree but also in the reverse direction to that given when conductors were used.

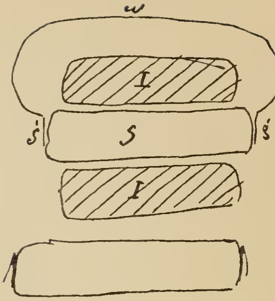
4643. Used a sulphur core with the same effect.

4644. Removed the sulphur and allowed only air as the core; still the same effect.

4645. But suspecting that the iron ring used in these cases might have a little unneutralized magnetism, I removed the wires connecting the galvanometer and the core, and then found that the same effect was produced. So that it was merely a little magnetism acting on the galvanometer needle, and not any effect of a current passing through its wires.

* [4638]





4646. Made the follng. arrangement. I, I the section of the iron ring; S the shell lac core; *w* a copper wire having 2 pieces of gold leaf hanging at *g*, *g* close to the ends of the core. On making and breaking contact of the ring wire with the galvanic battery, *no effect* on these gold leaves could be observed.

4647. Then suspended little strips on the tin foil coating the ends of the shell lac, but on making and breaking contact, no indication of repulsion could be observed. No signs that the dielectric became for the moment excited in a way to correspond with the formation of a current in the conducting core.

4648. So I cannot thus find any action on insulating bodies analagous to those which occur in conducting bodies: no transverse induction.

7 JUNE 1838.

4649. I was using the double plate Electrical machine and large Leyden battery to-day for the deflagration of some wires, and observed the following remarkable phenomenon.

4650. The battery was charged as highly as it would bear, and on being discharged through the wire, fell at once and *perfectly*, generally speaking. But on one occasion it was left with the electrometer divergent, and on Anderson proceeding to bring the charge up to a full degree, he called to me after eleven turns of the machine to say that the battery would not charge; the electrometer was down.

4651. I had during this time been engaged with my head near and thought it at first just possible that the points of the hair might have kept the charge down, but could not understand it.

4652. Continuing my experiment, the battery was again left charged, and the electrometer divergent after a discharge, and now I watched things; and, telling Anderson to work the machine, as he did so, the electrometer fell. It took nine turns of the machine to *reduce* the charge left in the battery to nought.

4653. Thus the battery had been left charged *negative* after these two discharges, and to an amount equal to 9 and 11 turns of the machine, from 20 to 25 turns giving a full charge.

4654. This effect most important and curious, and I think I see the cause, so as to be able to produce it at pleasure.

4655. Have made many explosions to-day with wires, etc. but have not obtained any thing like a residual *Neg. charge*, though I used long wires, helices, cores, etc. Often obtained a residuum of one half or two thirds of the charge, when very fine wires were used, and also several other interesting indications.

14 JUNE 1838.

4656. Have made many more explosions of fine wires, but did not obtain any result like that noted on the 7th instant.

21 JUNE 1838.

4657. Experimented on the effect of Polar arrangement of the particles of crystals on their specific inductive capacity, i.e. on their inductive capacity in different directions.

4658*. Arranged our large battery of 15 Leyden jars and connected it with the insulated brass conductor, at the further end of which was a rod terminating in a brass ball of an inch in diameter. This ball was to be the inductric object and to have its power sustained by the battery connected with it.

4659. The carrier ball of the Coulomb Electrometer was the inducteous body.

4660. A stem of shell lac, fixed on a foot, had a little plate of shell lac at the top which served to sustain cubes, etc. of crystallized matter. The stem was inches in length and only so thick as to have sufficient strength to support the cubes. It was so flexible that slight force was sufficient to bend it a little in any direction.

4661. When a cube was to be examined, the battery was first charged by 8 or 10 turns of the cylinder machine. Then the carrier ball was rendered neg. inducteously and used to charge the repelled ball of the Electrometer. Then the mutual repulsion of the balls was noticed. Then a cube was put upon the shell lac support and adjusted so that a horizontal line pass thgh. the middle of it and of the inductric ball at the end of the conductor. Then the cube was approached close to this ball, the carrier ball of the electrometer brought against the opposite face of the cube, the carrier ball uninsulated by a wire applied at the back in the same straight line—uninsulated—removed—the cube withdrawn 4 or 5

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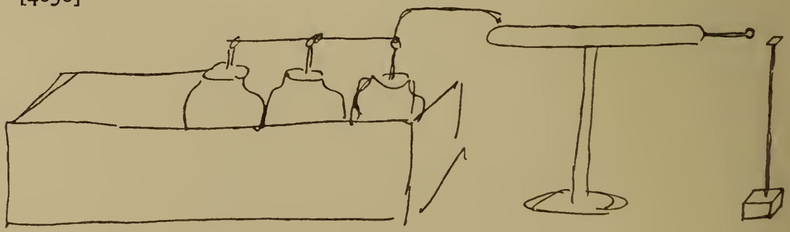
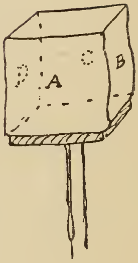
* [4658]



inches, and the carrier introduced into the Electrometer and its force measured at the constant angular distance of 30° as before. The following* is the arrangement of the inductric ball *a*; the cube *b*; the carrier ball *c*; and the discharging wire *d*.

4662. The first substance experimented with was iceland spar. I have had a cube of this substance cut; it is very clear, has no flaws or fissures, but there is a thin stratum of spar in another direction across it at one edge. It is only 0·5 of an inch in the side, being the largest that could be cut out of a considerable rhomboid. Two of the faces are perpendicular to the axis of the crystal, the other four faces are parallel to it. It is not varnished at present but in its natural state.

4663. This cube was put upon the shell lac stand so that the axis of the crystal was horizontal, as for instance in the direction from A to C. It is evident that each of the faces A, B, C, D could in turn be placed towards the Inductric ball and the carrier at the same time applied to the opposite face, the cube itself being the measure of the distance between the inductric and inducteous surfaces, and *its matter* the dielectric between.



4664. As before said, the process was to approach a face of the cube into contact with the inductric ball, bring the carrier ball against the opposite face in a constant position and direction, uninsulate it, insulate it, remove it; then remove the cube a few inches, and measure the force of the carrier. Then turning the shell lac stand 90°, another observation was made through the cube. Again the shell lac stand was turned 90° and the operation repeated, and also a fourth time, until observations had been made in four directions, twice along and twice across the axis of the crystal.

The balls in the Electrometer were 178°, Neg. charge.

1.	Force of the carrier—lines of induction	along the crystal axis	110°
2.	,, ,, ,, ,,	across ,, ,,	150°
3.	,, ,, ,, ,,	along ,, ,,	180°
4.	,, ,, ,, ,,	across ,, ,,	178°

After the last removal of the cube, it was examined as to its own state, and I found it was electrified, having received a charge like that of the Inductric surface. Hence the rise in force from

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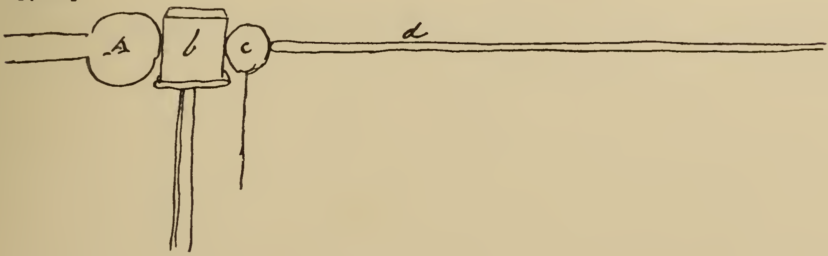
* [4661]



the first observation onwards. It has enough conducting power thus to acquire a charge by contact with the inductric ball.

4665. Cleared the cube of Electricity and experimented again, not bringing the inductric ball, the cube and the carrier into contact, but leaving a space of air between and trying by the eye to make this equal at all times. Of course the distance must be somewhat uncertain and liable to variations. The results were:

1.	Along the axis	69°
2.	Across ,,	65°
3.	Along ,,	55°
4.	Across ,,	52°

Here the effect *along* the axis was stronger than *across* it, but of course the result alone is worth nothing. The calc. spar cube was, at the end of the experiment, a little electric, *pos.*, or like the inductric ball.

4666*. I now fixed a little nipple of shell lac on the middle part of the inductric ball, to act as a stop to the approach of the cube, and at the same time to insulate the two and also give an invariable distance. The carrier ball was put each time in contact with the opposite face of the cube.

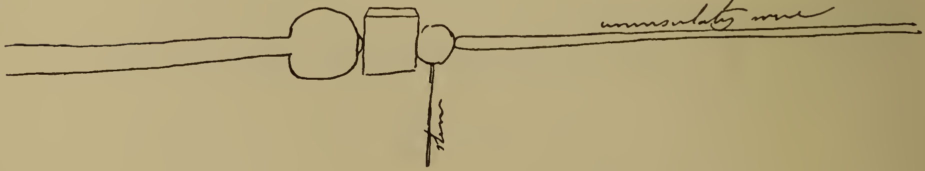
4667. The following observations were made:

1.	Along axis	127°	=	9.	Across axis	42°	+
2.	Across ,,	106°	+	10.	Along ,,	36°	=
3.	Along ,,	87°	=	11.	Across ,,	36°	+
4.	Across ,,	132°	+	12.	Along ,,	34°	=
5.	Along ,,	122°	=	13.	Across ,,	80°	+
6.	Across ,,	100°	+	14.	Across ,,	84°	+
7.	Along ,,	44°	=				
8.	Along ,,	45°	=				

4668. Here great irregularity—and now made a set of successive observations without changing the position of the crystal; i.e. withdrawing it each time, but always replacing it in the same relative position.

Along axis	97°
Do.	83°
Do.	70°
Do.	64°
Do.	50°

4669. Here a regular sinking. On examining the calc. spar cube



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* [4666]

I found it had received a charge, but it was of the reverse kind to the inductric ball, having become inducteously charged Neg. This was natural enough, considering that it was each time touched by the carrier ball and uninsulating wire and possesses a slight degree of conducting power. The consequence would be a gradual diminution of the action of the inductric ball on the carrier, because of the intervention of this body in the opposite state, that state gradually increasing in intensity with each observation from a repetition of the circumstances favouring its charge.

4670. Must *Varnish* the calcareous spar cube.

4671. Now experimented with a cube of rock crystal No. 2. It is very clear and good—free from flaws; 0·7 of an inch in the side—and is varnished thinly but well with solution of shell lac in Alcohol.

4672. First observed the effect in several successive observations, the position being in all the same. For until observations are steady in one position and direction, it is useless to compare the effect in different directions.

1.	Along crystalline axis	90°
2.	Same	88°
3.	Same	85°
4.	Same	62°
5.	Same	60°
6.	Same	59°

4673. On removing the cube last time, and examining it, I found it was inducteously charged Neg. So that it does the same thing as the calc. spar.

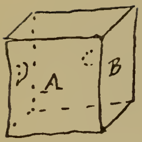
4674. The sudden effect from 85° to 62° I conclude is due to a harder contact than usual, breaking more or less through the film of shell lac on the cube, and so giving more or less opportunity for it to acquire the inducteous state.

4675. I then discharged the cube and made fresh observations, endeavouring *between each* to discharge the cube by touching it with the uninsulated wire, whilst out of the influence of the Inductric ball and surfaces.

1.	Along axis . .	148 . .	tried to discharge cube.
2.	same . . .	139 . .	Do.
3.	same . . .	128 . .	Do.

But at the end of the third observation, still found the cube neg.—so that discharge by wire had not been good, and indeed considering the feeble conducting power of the rock crystal, and its coating of shell lac, it was not likely such discharge would be good.

4676. I then discharged the cube quite and found it gave by same face and direction—109°, and as the cube on examination presented scarcely any charge, this fall from 128° to 109° is due mainly to the fall of the charge of the battery and the Electrometer.



4677. I now proceeded to make observations along and across the crystalline axis, but I did not rotate the cube for this purpose; on the contrary, I passed it in one direction through 90° and then back through 90°, then advanced it through 90° then again back. So that the face C was first towards the Inductric ball, then D, then C again, and so as follow: D, C, D, C, D. The results were:

1.	Along axis	.105		
			9	
2.	Across	. 96		
				1
3.	Along	. 95		
			9	
4.	Across	. 86		
				16
5.	Along	. 70		
			1	
6.	Across	. 69		
				2
7.	Along	. 67		
			3	
8.	Across	. 64		

4678. Found the cube charged neg. (or inducteously) at last and my fear is that it charges irregularly, i.e. not by equal or proportionate portions each time.

4679. Again the same experiment with the Quartz or rock crystal cube—balls re-charged, 210°.

	Across,		along, the axis
1.	215°		
		4	
2.			211°
		11	
3.	200°		
		29	
4.			171°
		11	
5.	160°		
		11	
6.			149°

4680. Here much irregularity. But the diminution of force continual and general, and the cube found charged in a Neg. state, i.e. opposite to the inductric ball.

4681. I now stuck two pimples of shell lac on the faces A and B of the cube, so that the carrier ball and its uninsulating wire *should not touch* the cube. The carrier ball was in each case brought to bear upon them. The results were now much more regular, and being intended to test the steadiness of the apparatus and arrangement, were made at first principally in one direction, thus:

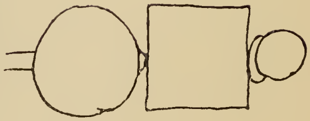
1.	Along axis	129°	7.	Along axis	105°
2.	same	133°	8.	same	109°
3.	same	126°	9.	across	100°
4.	same	120°	10.	across	88°
5.	same	120°	11.	across	90°
6.	same	120°	12.	along	92°

4682. Dust is a very serious inconvenience in carrying a charge from the inductric body to other bodies, as the cubes, etc. When the cube is put near the inductric ball, even without approach, etc. of carrier ball, it receives an inducteous charge, in the same manner as a conducting cube or particle would, and which I have described in series xiii.

22 JUNE 1838.

4683. I have varnished the iceland spar cube with shell lac varnish.

4684. I have removed the pimples of shell lac from the rock crystal cube, but have put a plate of shell lac on one side of the carrier ball, namely that side which is to be towards the inductric ball: the arrangement being such that the opposite side is to be towards the repelled ball of the electrometer when the carrier ball is in that instrument. As the inductric ball with its nipple, the cube, and the carrier ball with its coating, are always brought into contact, the distance between the inductric and the inducteous balls will always be the same.



4685. Used first the *iceland spar cube, varnished.*

balls, Neg. 155.

	along axis	across axis		along axis	across axis
1.	158°		10.		133°
2.	159°		11.	136°	
3.	157°		12.	128°	
4.	152°		13.	131°	
5.	150°		14.		120°
6.	146°		15.		119°
7.		141°	16.	121°	
8.		138°	17.	115°	
9.		134°			

4686. At the close, the cube had acquired the opposite state in a slight degree.

4687. The diminution of force in the carrier ball is now much slower than before and the observations more regular. As to the comparitive force in two directions, it sinks each time it passes from = to +, and rises each time it passes from + to =. So that if there be any difference, it seems in favour of the direction of the axis.

4688. Now experimented with the *Varnished Rock crystal cube.*

balls, Neg. 270°

	along =		along =	across +
1.	206°	6.		205°
2.	245°	7.		192°
3.	232°	8.		184°
4.	225°	9.	195°	
5.	222°	10.	201°	

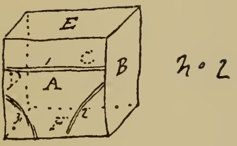
4689. Progression pretty fair—sudden fall from = to + and rise from + to =, as if direction of crystalline axis most favourable to induction.

Again

	along =	across +		along =	across +
1.		152°	9.		125°
2.		133°	10.	139°	
3.		132°	11.	131°	
4.		128°	12.		119°
5.	138°		13.	124°	
6.	140°		14.		118°
7.	133°		15.	123°	
8.		129°			

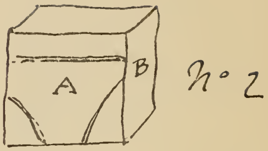
4690. Here again, evidence continues in favour of the crystalline axis.

4691. I must measure carefully hereafter the dimensions of the cube in these two directions.



4692. There are certain coloured layers (very faint) in the rock crystal cube, by which its position and its faces can be identified. These come out upon two faces and there form lines 1, 2 and 3; and as 2 is larger than 3, these two faces, and therefore all the rest, can be distinguished from each other. I will therefore mark them A, B, C, D, E, F.

4693. Now experimented with the rock crystal cube in this position on the table, and made successive observations, turning the cube 90° round between each, so as to bring each of the four faces, A, B, C, D in succession towards the inductric ball. I did this through seven complete revolutions of the cube, but I did not note accurately so as to be quite sure of the faces A and C. In the following results therefore, it may be that I have made a mistake in the appropriation of the letters to the faces, but not certainly as to the *along* or *across*, or as to the successive presentation of the contiguous and following faces.



4694. The cube of course remained at the same height during the experiment; and though not perfectly true on its stand, it was considered that the *two observations along or across from opposite sides* would give a mean result approaching to accuracy.

4695. *balls* 300°, *Neg.*

	along =	across +	along =	across +
D. 1		136°		
C. 2			142°	
B. 3				125°
A. 4	132°			
D. 5		122°		
C. 6			124°	
B. 7				114°
A. 8	124°			
D. 9		118°		
C. 10			113°	
B. 11				101°
A. 12	110°			
D. 13		102°		
C. 14			103°	
B. 15				95°
A. 16	103°			
D. 17		95°		
C. 18			93°	
B. 19				88°
A. 20	93°			
D. 21		92°		
C. 22			91°	
B. 23				78°
A. 24	90°			
D. 25		80°		
C. 26			80°	
B. 27				70°
A. 28	80°			

See (4774, 4775).

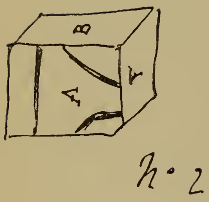
4696. Though the charge of the Electrometer balls is high, the charge of the inductric ball was but low, that more uniformity in the successive indications might be obtained. The letters note the faces of the cube which were towards the inductric ball.

4697. The second = is not so good as the first: and the first + is not so good as the second: probably because of slightly inclined position of the cube on the shell lac support. So the first = and + should be compared together, and also the second = and +. If the first + and the second = be compared, they will give a less difference than the mean. If the first = and the second + be compared, they will give a greater difference than the mean.

4698. During these observations, the cube had acquired a negative inducteous charge, but not of much strength.

4699. The general result of the observation [is] that the inductive action is stronger along the crystalline axis than across it, for every passage from across to along gives *increase* of power, and every passage from along to across gives *diminution* of power.

See Aug. 7 for summary.



4700. Next alter the cube into this position, so that the other two faces perpendicular to the axis shall come into the plane of rotation, and then into this position*, that the axis of the crystal may be perpendicular during the four successive observations across the cube.

25 JUNE 1838.

4701. Continued experiments with the Rock crystal cube No. 2. Arranged it so that the axis AC should continue in the horizontal plane, the line FE come into it, and the line BD go out of it, being now vertical and parallel to the axis of rotation. The results were as follows:

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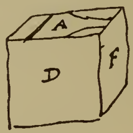
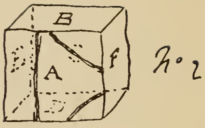
* [4700]



4702[1].

	C Along =		F across +		A along =		E across +	
1.	154							
2.		21 *3* 18	133					
3.				16 *2·25* 18·25	146			
4.						21 *2* 18	125	16 *1·75* 17·75
5.	141							
6.		14 *1·25* 12·75	127					
7.				13 *1·6* 14·6	140			
8.						18 *2* 16	122	11 *2·2* 13·2
9.	133							
10.		15 *2·2* 12·8	118					
11.				11 *1·25* 12·25	129			
12.						13 *1·25* 11·75	116	10 *1·12* 11·12
13.	126							
14.		6 *1* 5	120					
15.				1 *1·2* 2·2	121			
16.						9 *0·75* 8·25	112	16 *0·9* 16·9
17.	128							
18.		17 *1·6* 15·4	111					
19.				9 *1·6* 10·6	120			
20.						13 *1·9* 11·1	107	7 *1·75* 8·75
21.	114							
22.		10 *1·1* 8·9	104					
23.				11 *1* 12	115			
24.						11 *0·75* 10·25	104	



As before, the letters indicate the faces towards the Inductric ball.

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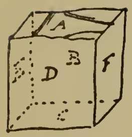
[1] Numbers in Italic type are written in red in the MS.

4703. The simple results of experiments shew that every time we pass from = to + there is diminution of force and every time we pass from + to = there is increase. Shewing as before the greater specific induction along the axis of the crystal than in the other direction, and so, combined with the former observations, it shews that the line AC or crystalline axis has greater force than either the line BD or that EF.

See Aug. 7, 1838 *for summary* (see 4776, 4777).

4704. The first small black figures shew the differences of each successive observation from its predecessor, but as there would be a gradual fall in force, that has to be taken from the differ. of = and + and added to the difference between + and =. I tried to get the falls thus: $\frac{1}{3}$ of the fall between observation 1 and 5 is 3·25: $\frac{1}{3}$ of that between observation 2 and 6 is 1·50: $\frac{1}{3}$ of that between 3 and 7 is 1·50, and $\frac{1}{3}$ of that between 4 and 8 is 0·75. These added together and divided by 4 makes 1·75 as the probable fall between observations 4 and 5, and it is so taken and expressed in Red ink[1]. Then adding and subtracting these falls so obtained for all the rest, wherever it is needful, the final black numbers come out as the differences each time of elevation and depression of force in passing from + to = and on to + again[2].

4705. There are evidently erroneous results due to interfering circumstances, amongst which I think the effect of the dust in the air upon the charge of the carrier ball, whilst carrying it from the one room to the other where the electrometer was, is the principle. But down to observation 12 there is much approach to regularity, and it does away entirely with the notion that any partial charge of the rock cube could produce the difference, for the complete revolution of the cube would of course ultimately counteract that effect: for if due to a charge of the cube, then being greatest for the axis in one direction, it would be weakest for it in the reverse observation, as the cube was gradually carried round through 360°.



N° 2

4706. I now placed the rock crystal cube thus, so that, as it revolved, the crystalline axis should be continually vertical, and the observations in the four positions of the cube be always across it. This would of course test the effect of a probable partial charge of the cube with Electricity. The results were as follows:

---

[1] i.e. in italics.

[2] Certain arithmetical errors in this paragraph and in the table (par. 4702) are evident; they have been left unaltered.

4707.

E		B		F		D	
+		+		+		+	
133							
	2						
		131					
			4				
				127			
					3		
						124	
							5
119							
	0						
		119					
			3				
				116			
					4		
						112	
							4
108							
	4						
		104					
			1				
				103			
					4		
						107	

See Aug. 7, 1838 (4778, etc.).

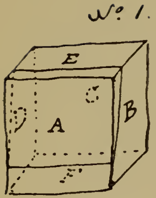
4708. At the last observation, the cube was deranged on the stand and had been touched; the observation therefore should not count. Prior to that, it will be seen that the force *continually diminished*, never rising (though in observations of this kind, if a rising indication had appeared, it would not have been wonderful). In the next place, the diminution has all the characters of the gradual fall due to the lowering of the force at the battery and electrometer. With all the errors upon it, it is never more than 5 between two successive observations or less than 1, giving a difference of 4; whereas in the former observation it was in one direction 21 and in the other 16, giving a difference of 37.

See Aug. 7, 1838.

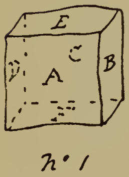
4709. These set of observations therefore confirm the results as to the former two sets, that the axis does favour electrical induction more than the other directions.

4710. Now examd. the measurement of the cube, to ascertain if the thickness were the same in the three directions. Found that the direction AC was the greatest by a minute quantity, for compass points passing stifly over the faces AC passed easily over the faces BD or EF. The linear dimension of the cube was 0·7 of an inch.

4711. As the distance through which inductive action was exerted was measd. by the cubes and the pieces of shell lac on the inductric and carrier ball, so it has been greater rather than less along the line of the crystalline axis.



4712. Worked with the iceland spar cube No. 1 again. This cube, as before said, is nearly 0·5 of an inch in the side. It is very clear, but has a place [? plate] of spar crystallized in another direction, running across it in such a manner that all the faces can be identified. This plate is indicated in the figure by the red lines[1]. Now from face A to face C is the direction of the crystalline axis—and therefore across this interposed plate; from B to D and from E to F are directions across the crystalline axis.



4713.	C	B	A	D	balls Neg. 260°
	=	+	=	+	
	166				
		159			
			158		
				159	
	157				
		154			
			153		
				150	
	148				
		143			
			138		
				138	
	137				
		135			
			137		
				128	
	126				
		125			
			125		
				118	

See Aug. 7, 1838 (4781).

---

[1] The lines across the faces are drawn in red.

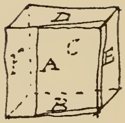
4714. At the end the cube was electric, inducteously or Negative.

4715. Here there is no appearance that crystalline axis directn. AC, and the cross direction BD, differ. They seem nearly if not quite alike. No evident result here.

4716. Now compared the crystalline axis direction AC with the other cross direction EF, thus:

Iceland Spar No. 1 varnished.

C	E	A	F
=	+	=	+
134			
	126		
		131	
			128
123			
	121		
		121	
			118
117			
	112		
		114	
			109
108			
	104		
		106	
			104



No 1

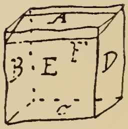
See 7 Aug. 1838 (4784).

4717. Here there seems to be a little superiority along the crystalline axis, as if direction AC surpassed direction EF.

4718. Upon that it would follow that direction BD would also surpass EF. Tried the experiment.

balls 290°

B	F	D	E
+	+	+	+
265			
	237		
		255	
			227
245			
	218		
		229	
			225
222			
	208		
		226	
			198



No 1

[See] 7 Aug. 1838 (4787).

4719. Here BD direction does surpass EF direction, but more than I expected, and I think more than crystalline direction does: but must remember the balls of Electrometer have been charged again.

4720. I now again made the observations, with the cube so placed that its crystalline axis was vertical—but though I revolved the cube as before, I refrained from ascertaining at which face I began until afterwards, so that I might not know what to expect; then when the observations were made, I ascertained at what face I began and attached the letters to the observations thus:

balls 300° Neg.

1.	260			
2.		240		
3.			249	
4.				232
5.	235			
6.		217		
7.			224	
8.				214
10[1].	217			
11.		195		
12.			204	
13.				187
	D	E	B	F
	+	+	+	+

See 7 Aug. 1838 (4790).

4721. Here again, however, the direction BD distinctly and considerably surpasses that of EF.

4722. Directly after the eight[h] observation, I repeated it, not moving the crystal 90° round, but again bringing face F towards the inductric ball, and the result was again 214°, so that the previous and the succeeding rise in force could hardly by any possibility have been accidental.

4723. After the last observation, I made the repelled ball of the Electrometer Pos., then brought the shell lac of the carrier against the four faces of the cube in succession, touching with the wire, and so on, to give it its due inductive charge, and found that these were

D	E	B	F	
12°	12°	11°	12°	and positive

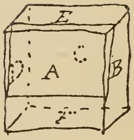
---

[1] 9 is omitted.

4725[1]. This shews that the cube had therefore become inducteous or negative, but very equally in all directions and parts, so that no irregularity of its charge could have produced the constant difference between direction BD and EF.

4726. But if direction BD thus surpasses EF and does not surpass the crystalline axis direction AC (   ), then the latter ought more distinctly to surpass EF than it appears to do. First however, compared direction AC and BD (being the two good ones) together again (   ).

4728[2].	D	C	B	A	balls Neg. 300°
	+	=	+	=	
	290				
		305			
			286		
				285	
	275				
		273			
			263		
				257	
	248				
		252			
			248		
				233	
	232				
		232			See 7 Aug. (4792)
			216		
				218	
	215				
		211			
			197		
				196	



Nº 1

4729. Here the results are not clear. There are only three risings, but they are in proceeding from + to =. Again, as to the fallings, those from + to = are on the average less than those from = to +, so that if the constant successive loss were added and subtracted, more of the difference from + to = would be rising differences, whilst the others would of course be smaller descending differences.

4730. So also taking all the differen. from + to =, the average descent is only 0·8 of a degree of force; whereas the average descent from = to + is 9·5°.

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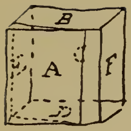
[1] Par. 4724 is omitted in the MS.

[2] Par. 4727 is omitted in the MS.

4731. Hence the crystalline axis direction appears decidedly to surpass direction BD.

4732[1]. Now how is it with regard to direction EF, which appears to be so weak in comparison with BD?



No. 1

balls $460^{\smile}$

E		C		F		A	
+		=		+		=	
270	*2*	268	*16*	252	*2*	254	*3*
251	*9*	242	*0*	242	*10*	232	*13*
245	*3*	242	*15*	227	*5*	222	*2*
220	*2*	218	*10*	208	*0*	208	*6*
202	*4*	198	*5*	193	*1*	194	

See (4794).

---

[1] The figures in italics in this table are in pencil in the MS.

4733. Here there are three rising, two small from + to = and one large from = to +; they tell nothing therefore. Nor does the general appearance of the differences tell much. The average descent is 3·2 from + to = and 5 from = to +. So that though + direction of EF appears to be a little weaker than along direction, yet it is not so much weaker, as might have been expected from the relation of it to BD; and indeed crystalline directn. AC surpasses directn. BD far more than it does directn. EF. Yet EF is greatly under BD direction in power when they are compared together.

4734. Must experiment with this cube again. Perhaps the interposed layer may disturb the results. Get also a clear cube.

4735. Wished now to compare Specific inductive force of air and these cubes. Arranged stops so that the carrier could be placed again and again at a certain constant distance from the inductric ball and there be touched by the discharge wires, insulated, removed and its force measured, and then be restored to the same place. Made this distance such that the rock crystal cube could be introduced easily, there being then a little interval of air between it and the carrier and also between it and the inductric ball.

4736.

1.	When the whole interval was air, the force was	102°
2.	When rock crystal cube = crystalline axis	186
3.	Air again	92
4.	Rock crystal cube + crystalline axis	158
5.	Air	86
6.	Rock crystal cube = axis	162
7.	Air	82
	Calcareous spar cube No. 1	95
	Do. again	90
	Air	75

4737. As regards rock crystal, the superior specific inductive capacity of it, as compared to air, very evident, and also the superior capacity = as compared to +.

4738. With respect to the calcareous spar, as the whole distance between the inductric and the inducteous balls was about 0·85 of an inch, and it only 0·5 of an inch in size, it was evident that the comparison was unfavourable. Therefore made the distance between the inductric ball and the carrier smaller—as small indeed as consisted with the easy introduction of the calcareous spar cube; now:

Air in the whole interval—force equalled 88°
Iceland spar cube there „ „ 148

So that superior inductive capacity of it very evident.

4739. Looking at data of the preceeding page[1], the mean of
observations 1 and 7 gives 92° for air.
observations 3 and 5 „ 89° for air.
observation 4 „ 158° rock crystal + crystl. axis.
observations 2 and 6 „ 174° „ „ = crystl. axis.

4740. The successive falls in force being supposed to compensate each other with respect to the time of the fourth or middle observation—and the two results as to air favour such a view. Hence the other expressions approach towds. those belonging to the cube, but are of course under the mark as to the power of rock crystal if the whole of the dielectric were of that substance.

4741. In establishing Specific inductive action, it may be supposed that if the dielectrics used have a little conducting power, they may become polar as masses as conductors do, and so give a stronger inductive force across them; and though the former experiments are sufficient to shew that the double power of shell lac, sulphur, etc. cannot be due to that cause, I will refer again to it here, because the cubes used frequently present an ultimate charge.

4742. The former experiments referred to are these: first that unelectrified plates of sulphur and shell lac, when between the differential inductometer plates for a moment only, shew their full specific inductive action—when brought away, come away uncharged; and if put into the neighbourhood of an inductric surface and be then touched without friction by a metallic uninsulated ball and immediately withdrawn and examined, they still also receive no charge. Whereas if they conducted enough to become polar as masses, and so shew a greater inductive capacity, they would certainly in the latter case become charged also inducteously, and to a serious degree.

4743. The next fact or set of effects is, that a little polarity of the mass due to a little conducting power would not be sufficient—for that the specific inductive effect of shell lac is equal to that produced by a diminution of the interval to perhaps *one half*, if air be retained in the apparatus—as the former experiments shew.

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[1] Par. 4736.

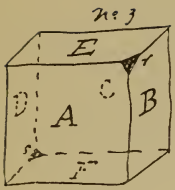
4744. The electricity which a non conducting dielectric acquires by the carrying power of dust, etc, etc. cannot give the appearance of a greater specific inductive capacity. Its general action will be to diminish the charge the carrier ball will receive, not to increase it, for its electricity is of the *contrary* kind to that of the Inductric body; besides which it would never produce any thing like the difference along and across the crystalline axis, but only one common enfeebling effect in all position[s].

4745. However, I experimented with a cube of shell lac in place of the crystd. cubes. It was at first quite clear of any electricity. Then it was used as the other cubes had been; gave 320° of force to the carrier ball—it was withdrawn—the electrometer repelled ball charged Pos.—the battery and conductor discharged—then the carrier ball was held close to the shell lac in the usual manner to receive a Pos. charge by induction, if the lac were itself negative—and I did in fact obtain the least possible degree of repulsion, but it was hardly sensible. So the shell lac had acquired a very feeble neg. charge at the part nearest to the inductric ball.

4746. Tried sulphur in the same way. It received no charge during the time of the observation.

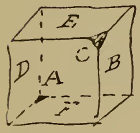
4747. Taking up the electric state of charge has nothing therefore to do with the variation of Specific Inductive capacity.

6 AUG. 1838.



4748. Have had another fine cube of *iceland spar* cut by Mr Darker from spar given by Mr Brooke to him. It has no cross plate or veins, is quite uniform in quality, and is rather more than 0·8 of an inch in the side. It may be distinguished *as No.* 3 *cube.* AC is parallel to axis–BD across axis–EF across axis. At two opposite solid angles, small portions of the original faces of the Rhomboid remain; one of these is a little larger than the other, *r*, *s*. They serve to distinguish and identify all the faces of the cube.

4749. Have had a new and good insulating table for cube arranged and worked as before (   ).



No 3

4750. No. 3 Iceland spar cube, 0·8 of inch.

faces	A	B	C	D	balls 250
	=	+	=	+	
	474				
		487			
			466		
				458	
	428				
		415			
			416		
				398	
	390				
		381			
			364		
				357	
	295				
		304			
			294		
				285	
	266				
		275			
			262		
				257	

The cube at the end was electrified a little only and in the opposite state, i.e. Neg.; the Inductric ball being positive.

4751. Here there are four rising, three rather considerable, from = to +; and one very small from + to =.

4752. The falls are numerous and irregular, but those from = to + are less much than those from + to along.

4753. The average of the ten intervals or differences from = to + is only a fall of 3·8, but the average of the 9 differences between or from + to = is 20, when the great fall of 62 is included, and when that is left out the average fall of the eight difference[s] is 14·7.

4754. Here therefore the across direction BD would appear to have a greater inductive capacity than the along or axial direction AC.

4755. Used same cube of Iceland Spar No. 3, so as to compare directions AC and EF (was first quite discharged).

faces towards inductric ball

A	E	C	F	balls 260
=	+	=	+	
225				
	225			
		215		
			214	
205				
	204			
		195		
			192	
186				
	178			
		174		
			173	
164				
	167			
		158		
			156	
145				
	147			
		140		
			141	
132				
	132			
		123		
			125	

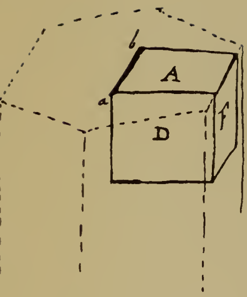
4756. The cube was left very slightly charged—hardly sensible but Neg. or opposite to the Inductric ball. The low degrees of charge appear to give most steady results.

4757. There are four risings, all small but all from = to +.
There are two 0—both from = to +.

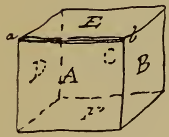
There are seventeen fallings, of which only six are from = to +, whilst eleven are from + to = and are also greater in amount.

4758. The average of the 12 differences from = to + is only a fall of 0°·666 for each—whilst the average of the 11 differences from + to = is a fall as great of 8°·36 for each. So here also the cross direction, i.e. the direction of EF, appears to have a greater inductive capacity than the along direction AC.

4759. Mr Darker has also cut me another beautiful rock crystal cube. Its position in the rock crystal prism is as represented, and the edge *ab* (all the edges being a little bevelled) is a little more bevelled than the rest and also polished, so that all the faces of this cube can be identified. The cube is very perfect, gives exceedingly well defined rings by polarized light in the direction AC, and is 0·77 inches in the side. It is called No. 4, and like the other cubes was covered with a thin coat of shell lac dissolved in Alcohol.



N°. 4.



N°. 4

Proceeded to experiment.

4760.

	A	B	C	D	
	=	+	=	+	balls about 400°
	382				
		355			
			360		
				362	
	377				
		345			
			351		
				355	
	346				
		325			
			335		
				326	
	315				
		298			
			306		
				295	
	285				
		265			
			275		
				257	
	250				
		245			
			236		
				235	

I was then interrupted for a little while, after which the observations were resumed; thus:

4761.

A	B	C	D
=	+	=	+
		227	
			231
219			
	215		
		216	
			209
205			
	189		
		195	

4762. Now taking the first part of the set of observations. There are 8 risings, of which 6 rather considerable are from + to = and 2 much smaller are from = to +. There are 15 fallings, of which 10, and many of them considerable, are from = to +, and 5, less than the former, are from + to =.

4763. The average of the 12 differences from = to + is a fall of 13° per difference—the average of the 11 differences from + to = is a rise of 0·73 per difference.

4764. So that here the axial direction has a decided advantage or a greater Specific inductive capacity.

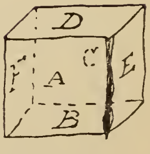
4765. As to the part below—there are three risings, two from + to = and one from = to +. There are five fallings, three from = to + and two from + to =.

4766. The average of the four differences from = to + is 5°·75 of fall per difference. The average of the four differences from + to = is 2°·25 of fall per difference.

4767. So that here again, the axial direction is apparently of greater specific inductive capacity than the cross direction, though the difference is less.

4768. Now worked with cube rock crystal No. 4, using faces A E C F and began with face E.

A	E	C	F
=	+	=	+
	199		
		195	
			186
175			



No 4

A	E	C	F
=	+	=	+
	177		
		172	
			169
156			
	152		
		152	
			150
150			
	141		
		143	
			132
126			
	117		
		125	
			123
117			
	111		
		114	
			111
105			
	100		

4769. Here are four risings, three being from + to = and one from = to +.

There are two 0°, both being from + to =.

There are eighteen fallings, of which 11 are from = to + and 7 are from + to =.

4770. The average of the 12 differences from = to + is a fall of 5° per difference. The average of the 12 differences from + to = is 3°·17 per difference.

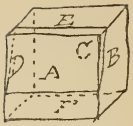
4771. So here axial direction gives greater specific inductive capacity than the cross direction, though the difference is not so great as in higher degrees of former observation—but more like lower degrees.

4772. Perhaps all the three directions differ, and they may well do so considering how the cube is related to the original crystal—for this, compare directions EF and BD together by experiment.

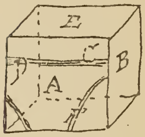
4773. The following is intended to be a list of the cubes for reference:

AC along optical axis =
BD across " " +
EF across " " +

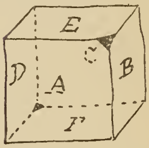
No. 1. Iceland spar—with a cross place—0·5 inches in the side.



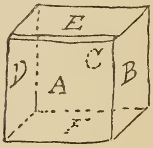
No. 2. Rock crystal—coloured veins—0·7 of inch in side.



No. 3. Iceland spar—two solid angles replaced by small natural planes—0·8 inches in side.



No. 4. Rock crystal—one edge polished—0·77 in side.



AUG. 7, 1838.

4774. The results of the series of observations on the Rock crystal cube No. 2, of 22 June (4695) is as follows:

There are ten risings—all are from + to =.

There is one 0°—from + to =.

There are sixteen fallings, of which 13 are from = to + and three only from + to along.

4775. The average of the thirteen differences from = to + is 9° fall for each difference. The average of the fourteen differences from + to = is 4°·4 of rise for each difference.

This is a very striking result.

4776. Again, the results of the series of 24 observations obtained with the same Cube No. 2 of Rock crystal on the 25th June (4702) are as follows:

There are eleven risings, all from + to =; *every* passage from + to = is a rise.

There are twelve fallings, all from = to +; *every* passage from = to + is a fall.

4777. The average of the eleven differences from + to = is a rise of 10°·7 per difference. The average of the twelve differences from = to + is a fall of 14° per difference.

This is a very striking result. If it is all due to the crystallization.

4778. Again, the results of the series of 12 observations of the 25th June (4707), where direction of EF and BD of the cube No. 2 were compared, are as follows:

4779. There is but one rise and it is in passing from the direction EF to that of BD. There is also only one 0°, and that is in going from direction FE to that of DB.

Six observations passing from direction EF to BD give an average fall of 1°·5 for each difference—five observations passing from direction BD to EF give an average fall of 3°·4 degrees. But there is a doubtful observation in the first six, and that being left out, it makes the average fall 2°·6 from direction EF to BD.

4780. This differ. of 0·8 of a degree in favour of one direction over the other may be accidental or may be real, and due to the different relations of these two directions to the axis of the original crystal.

4781. Now brought out the results of 25 June (4713) with Iceland spar cube No. 1, on faces A, B, C, D.

There are two small risings, one from + to =; the other from = to +.

There are two 0°, one from + to =; the other from = to +.

4782. The ten observations from = to + give an average fall of 3·6 for each difference or passage. The nine observations from + to = give an average fall of 1·33 for each observation.

4783. So that here the axial direction seems to have somewhat more of specific inductive capacity than the transverse direction BD.

4784. Results of same date, 25 June, with same cube of Iceland spar, No. 1, using faces A, C, E, F (4716).

There are three rising, all from + to =.

There is one 0°, also from + to =.

There are 11 falling; 8 from = to + and 3 from + to =.

4785. The 8 observations from = to + give an average fall of 4° per observation. The seven observations from + to = give a rise of 0·3 for each observation.

4786. So here, the axial direction seem to have greater S. Inductive capacity than transverse, and also by comparison with the former, to surpass direction EF more than it did that of BD.

4787. Results of same date with same calc spar cube, No. 1, using faces B, D, E, F (4718).

There are four rising, all in passing from FE to DB.

There are seven falling, six in passing from BD to FE and one in going from FE to BD.

4788. The six passings from BD to FE give an average fall of 21·5 per observation. The five from FE to BD give an average rise of 12°·4 per observation.

4789. So here, direction across BD has apparently a very much greater capacity than the cross direction FE. This does not agree with the former results.

4790. Results of 25 June with calc spar cube No. 1 on faces D, E, B, F (4720), unknown until afterwds.

All the 5 passings from direction EF to BD are *rising*.

All the 6 ,, ,, DB to EF are *falling*.

4791. The five from EF to DB give an average rise of 6°·2 for each observation. The six from DB to EF give a fall of 17°·33 for each observation. So that cross direction DB seems greatly to surpass the cross direction EF in degree of specific inductive capacity.

4792. Results of 25 June, No. 1 calc spar, with faces D, C, B, A (4728), 19 observations.

3 risings going from + to =.

10 going from + to =.

15 fallings–6 from + to =; and 9 from = to +.

4793. The ten differences from + to = give an average of 0·8 of fall for each. The nine differences from = to + give an average of 9·55 of fall for each.

So here = much surpasses +.

4794. Results of 25 June, No. 1 calc spar with faces E, C, F, A (4732), 19 observations or differences.

2 small risings from + to =, one large one from = to +; one 0 from across to along–one 0 from = to +.

4795. The 10 differences from + to = give an average of 3·2 fall for each. The 9 differences from = to + give an average of 5° fall for each.

So here, along surpasses across direction.

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4796. Separate the indications of the three directions into six and compare them together. The direction BD may not shew the same power of induction, when the face B or that D is towards the Inductric ball. Probably there ought to be no difference, but at all events examine the numbers.

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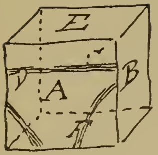
4797. Re-experimented with the Rock crystal No. 2 in all directions and manners, for the purpose of accumulating data and obtaining a good average result.

4798. Placed it with EF vertical and observed on the faces B, C, D, A, having first brought these faces in succession against the Inductric ball, in the same order, to give them what charge they would take: then



B	C	D	A	balls 260°
+	=	+	=	
228				
	251			
		223		
			232	
218				
	213			
		204		
			226	
207				
	207			
		199		
			213	
198				
	202			
		195		
			209	
192				
	193			
		188		
			207	
183				
	185			
		174		
			186	
177				
	181			
		166		
			177	
164				

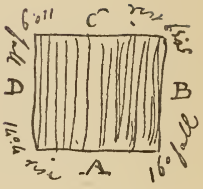
4799. All the transfers from + to = are rising, except one 0° and one which falls 5°.

All the transfers from = to + are fallings.

4780*. The 14 intervals from + to = give an average rise of 9°·3. The 14 intervals from = to + give an average fall of 13°·9.

4781*. So that the crystalline direction would seem to have much greater capacity for the induction than the cross arrangement.

4782*. Again, as to the separation into four directions as the faces are towards the Inductric ball.



From	+ to =	as first,	face	B	and then	C	on to inductric ball		5°·57	rise
,,	+ to =	,,	,,	D	,,	A	,,	,,	14·4	rise
,,	= to +	,,	,,	A	,,	B	,,	,,	16°·0	fall
,,	= to +	,,	,,	C	,,	D	,,	,,	11°·9	fall

4783*. Look at it thus, however.

The sum of the seven first observations at face B is 1403
,, ,, observations at C is 1432
,, ,, ,, D is 1349
,, ,, ,, A is 1450

But during the 28 observations, there has been a final loss of 64°—therefore those at C being increased by a fourth part of that loss; those at D by two fourths, and those at A by three fourths, the sums, divided by 7, give the average value of inductive force for the directions.

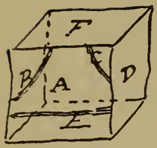
$$\left.\begin{array}{l} = \text{ when A is to the inductric ball—}214^\circ \\ = \quad ,, \quad \text{C} \quad ,, \quad ,, \quad 207^\circ \end{array}\right\} = 210^\circ{\cdot}5$$

$$\left.\begin{array}{l} + \quad ,, \quad \text{B} \quad ,, \quad ,, \quad 200^\circ{\cdot}4 \\ + \quad ,, \quad \text{D} \quad ,, \quad ,, \quad 197^\circ{\cdot}3 \end{array}\right\} = 198^\circ{\cdot}8$$

or on the average, 210°·5 for = and 198°·8 for +

4784*. The amount of rising and falling drawn from this average estimate differs from that given before, and simply for this reason, that the former have to include the whole fall or at least a seventh part of it or 9°·14, and this of course makes the risings less and the fallings more.

4785*. I then used the same cube No. 2 and the *same faces*, but I inverted the line joining E, F so that any irregularity of the shell lac support, which might cause a difference, might now be in the contrary direction; and I observed the faces in a different order, but touching the faces first as before.



4786*.

D	C	B	A	balls 440
+	=	+	=	
330				
	367			
		338		
			355	
312				
	339			
		318		
			331	
304				
	314			
		293		
			306	
300				
	313			
		308		
			314	
283				
	295			
		279		
			305	
260				

4787*. All the intervals from + to = rise.
All those from = to + fall.

4788*. The 10 intervals from + to = give an average rise of 17°·4. The 10 intervals from = to + give an average fall of 24°·4—the average fall between each two observatns. being 3·5 of real depression and the rest being the consequence of increased or diminished Spec. inductive capacity, according to the = or + direction.

4789*. The five first observations of D are 1529
,, observations of C ,, 1628
,, ,, B ,, 1536
,, ,, A ,, 1611

The loss during the 20 observations is 70°, so adding as before one fourth to C, two fourths to B, three fourths to A, and dividing the numbers by five (for the repetitions), it gives the average value of inductive force for the directions

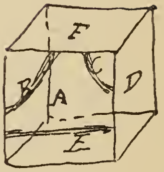
$$\begin{array}{lllll} = & \text{when A is to the inductric ball—} & 332{\cdot}7 & \rbrace & = 330^\circ{\cdot}9 \\ = & \text{,, C ,, ,, ,,} & 329{\cdot}1 & \rbrace & \\ + & \text{,, B ,, ,, ,,} & 314{\cdot}2 & \rbrace & = 310^\circ{\cdot}0 \\ + & \text{,, D ,, ,, ,,} & 305{\cdot}8 & \rbrace & \end{array}$$

4790*. Thus, still the = surpasses the + in specific inductive capacity—but besides that, A a little surpasses C, both being =, and B surpasses D, both being +: and such was also the case before, and about in the same proportion.

4791*. Again experimented with the same cube and the *same faces*, but turned it half way round on the supporting table, so that any irregularity in it might shew any effect it could produce. Also began now to observe at a different face, but I considered the electrometer ball and also the battery charge high enough to go on with from the last experiment. The half turn, of course, reversed C and A and also B and D with respect to each other and irregular position on the table of support.

4792*.

C	E	A	D
296			
	253		
		287	
			250
286			
	266		
		270	
			247
268			
	244		
		255	
			228
246			
	238		
		246	
			231
258			
	230		
		250	
			222
231			
	220		
		229	
			218
223			



4793*. All the intervals from + to = rise.
All those from = to + fall.

4794*. The 12 intervals from + to = give an average rise of 16°·83. The 12 intervals from = to + give an average fall of 23°.

The real fall of the apparatus between each two observations being therefore 3°·08.

4795*. The six first observations of C are—1585
The six observations „ B „ 1451
„ „ A „ 1537
„ „ D „ 1396

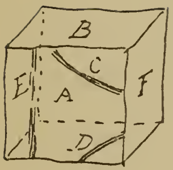
The loss during the 24 observations is 73—so proceeding as before, the average inductive force for the direction

= when A is to the inductric ball—262·1 } 263·1 =
= „ C „ „ „ 264·1 }
+ „ B „ „ „ 244·8 } 243·2 +
+ „ D „ „ „ 241·6 }

4796*. Here again, = surpasses +: but A is a little lower than C and also B but little above D.

4797*. Set about comparing directions AC and EF, and for this purpose placed the cube No. 2 as before, so that face B was uppermost and D beneath. The observations were begun with face C to inductric ball, and carried on in the order C, E, A, F, to the amount of eight recurrences of the whole series; except that order was reversed as indicated after a time.

4798*. After that was done (see following page[1]), I did not turn the cube upside down—thinking the effect of that change sufficiently shewn in the former case of that chance.



4799*. balls 560. No. 2 R. crystal.

C	E	A	F
=	+	=	+
389			
	368		
		382	
			348
370			
	350		
		373	
			331
358			
	332		
		347	
			323

---

[1] Par. 4799*.

329				
	310			
		336		
			314	Reversed the order of observation here.
		328		
	313			
337				
			302	
		300		
	287			
311				
			289	
		289		
	272			
300				
			277	
		294		
	273			
282				
			268	

4800. All the transfers from + to = were ascending (notwithstanding the change of order in the middle of the observations) except two: one of them being 0 and the other a fall of 2°.

All the transfers from = to + were falls.

4801. The 15 intervals from + to = give an average rise of 16°·4. The 16 intervals from = to + give an average fall of 23°. So that 3°·3 is the average fall of the apparatus electricity between each two contiguous observations. Hence direction = seems far more powerful in effect than direction +.

4802. The four first observations of C are 1446
,, ,, E ,, 1360 + 16·5 = 1376·5
,, ,, A ,, 1438 + 33 = 1471.
,, ,, F ,, 1316 + 49·5 = 1365·5

The average loss is 50° for the first $\frac{3}{4}$ of the time employed, or 66 therefore for the whole time; adding therefore $\frac{1}{4}$, $\frac{2}{4}$ or $\frac{3}{4}$ as before, it gives the inductive force for

= when A is to the inductric ball as 367·7 } 364·6 =
= ,, C ,, ,, 361·5
+ ,, E ,, ,, 344·1 } 342·7 +
+ ,, F ,, ,, 341·4

4803. The four last observations of C are 1230
,, ,, ,, E ,, 1145
,, ,, ,, A ,, 1211
,, 4th, 5th, 6th and 7th of F ,, 1182
} The order of observation being here reversed.

The average loss is 41·5 for the first three fourths of the time or 55°·3 for the whole time. Adding therefore $\frac{1}{4}$, $\frac{2}{4}$ and $\frac{3}{4}$ of this to A, E and C and dividing by 4, it gives the inductive force for

= when A is to the inductric ball as 306·2 } 312·1
= ,, C ,, ,, 318·0
+ ,, E ,, ,, 293·2 } 294·3
+ ,, F ,, ,, 295·5

4804. The 8 obs. of C added and divided by 8 gives 334·5
,, E ,, ,, 313·1
,, A ,, ,, 331·1
The first 7 obs. of F, the fourth being doubled,
being added and divided by 8 gives 312·2
So that in this way the inductive [force] for
= when A is to the inductric ball—331·1 } 332·8 =
= ,, C ,, ,, 334·5
+ ,, E ,, ,, 313·1 } 312·6 +
+ ,, F ,, ,, 312·2
So that in this way, = has Spec. Inductive capacity of 332·8
and + ,, ,, ,, 312·6,
whilst taking the mean of the two results given by the different halves of the set of observations, it is for
= ,, ,, ,, 338·3
+ ,, ,, ,, 318·5

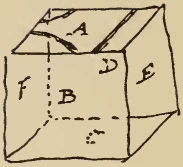
4805. The relation is the same, giving = as superior and nearly in the same proportion. The difference is due to the separate allowance made for constant loss in the case where the observations are taken in 2 sets, whereas when taken in one long set, the loss from the commencement to the middle is set against that from the middle to the end, whilst yet it is evident that the first is greater than the latter from higher intensity of charge, and therefore the two do not compensate each other. But the results are very near and striking enough as to their general character.

4806. I now compared the two cross directions together in the order B, E, D, F, the surface A of the cube being uppermost, thus, and then considered the examination of this cube sufficient.

4807.

+ B	+ E	+ D	+ F
258			
	257		
		243	
			248
242			
	241		
		229	
			234
228			
	238		
		228	
			220
226			
	215		
		213	
			211
215			
	216		
		205	
			211
214			
	203		
		194	
			198
189			
	196		
		195	

No. 2. Rock crystal. Balls and charge as left from the last series of observations.



4808. There are 7 risings and 6 fallings in passing from direction BD to that of EF.

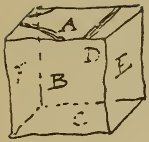
There are 3 risings and 10 fallings in passing from direction EF to that of BD.

4809. The 13 intervals from direction BD to that of EF give an average *rise* of 0°·3. The 13 intervals from direction EF to that of BD give an average fall of 5°·2—so that a fall of 2°·5 is nearly the mean for that between two observations.

4810. Here the cross direction EF appears to have a distinct advantage over the other cross direction BD—and yet BD is that direction in which the coloured veins rather go through from one surface to the other, in that respect resembling the direction AC.

4811. The first six observations of B give 1383
" " E " 1370 + 15 = 1385
" " D " 1312 + 30 = 1342
" " F " 1322 + 45 = 1367

The average loss during the six observations is 59°, so adding $\frac{1}{4}$, $\frac{2}{4}$, $\frac{3}{4}$ to E, D and F, and dividing by 6, it gives inductive force for



+ when E is to the inductric ball as 230·8
+ " B " " 230·5 No. 2.
+ " F " " 227·8
+ " D " " 223·7

4812. The average of E and F gives 229·3 for inductive capacity of that direction
" " B and D " 227·1 " "

and this agrees with the result or conclusion on the preceeding page at the bottom[1].

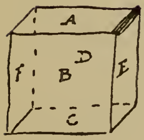
4813. That E and F are not both greater than B and D shews that it is not the mere parallelism of the direction EF or BD with the lines of inductive action that produces the differences, supposing they are not due to errors of experiment. Perhaps the result may be due to the direction of the line in reference to the inductric and inducteous surfaces; but in that case, if the inductric ball were charged negatively, although the direction EF should beat that of BD, still when resolved into the four observations, D ought to be better than B and F better than E; but the *sums* of DB and of FE ought to have the same relation as now.

4814. Enquire into this when I have time.

4815. I must now examine the former results with this cube 2 and collate them in one table.

4816. *Proceeded to re-observe with the Rock crystal cube No. 4.*

4817. I first took it with the optical axis vertical, so as to have induction in the cross direction. The face A was uppermost and the observations were successively on B, E, D, F.



	+ B	+ E	+ D	+ F	balls 340
. .	295				
. . . . .		308			
. . . .			318		Rock crystal No. 4.
. . . .				310	

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[1] Par. 4810.

284				
	285			
		290		
			291	
285				
	283			
		282		
			278	
260				
	255			
		262		
			258	
249				
	250			
		250		
			248	order of observation changed here.
		243		
	230			
226				
			235	
		230		
	220			
210				
			222	

4818. There are 4 risings and 10 fallings in passing from direction BD to that of EF. There are 3 risings, a 0 and 9 fallings in passing from direction EF to that of BD.

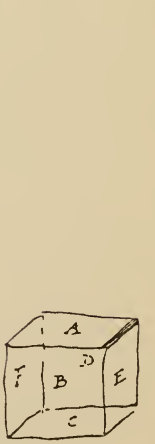
4819. The 14 intervals from BD to EF give an average fall of 0·8 per interval. The 13 intervals in passing from direction EF to that of BD give an average fall of 4°·8. So that direction EF somewhat surpasses that of BD, though both are +. That was also the case with the cube of rock crystal No. 2, but I do not know how those faces stood in the original crystal.

4820. Taking the first five observations, they make for

B − 1373	÷ 4 = 343·2
E − 1381	+ 18 = 1399 ÷ 4 = 349·7
D − 1402	+ 36 = 1438 ÷ 4 = 359·5
F − 1385	+ 54 = 1439 ÷ 4 = 359·7

The average loss during the five observations is 73, so adding $\frac{1}{4}$, $\frac{2}{4}$, and $\frac{3}{4}$ to E, D and F and divg. by five, it gives for

+ when F is to the inductric ball—359·7
+ „ D „ „ 359·5 No. 4. Rock crystal.
+ „ E „ „ 349·7
+ „ B „ „ 343·2



The average of E and F gives 354·7} as inductive capacities in
„ „ B and D „ 351·6} these directions,
according with the deduction in the last page[1].

4821. Here again then, the same direction differs according as its terminal faces are towards the Inductric ball, F and D, the ends of two cross directions, being very nearly alike. But the difference is not very great and there may be errors of experiment here.

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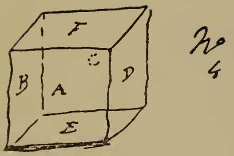

4822. Proceeded to compare the = direction with the two + directns. of Cube No. 4 Rock crystal. The face F was placed upwards and the faces A, B, C, D were observed in that order. The results are on the next page[2]. The charge of the apparatus fell fast to-day. It was principally in the battery; the glass column of the Rubber I think was cool. It would be well to remove that connection perhaps during observations.

4823.

A	B	C	D	balls 360°
383				
	363			
		346		
			336	
325				
	303			
		302		
			286	
278				
	263			
		255		
			250	
233				
	222			
		217		
			208	
194				
	187			
		186		
			175	
167				
	157			
		157		
			146	
144				

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[1] Par. 4819.

[2] Par. 4823.

4824. There is not one rise in these intervals. There is only one 0 and that is in passing from + to =.

4825. The 12 intervals from + to = give an average fall of 6°·8. The 12 intervals from = to + give an average fall of 12°·2. So that the average fall of the apparatus for each interval is 9°·5. The rest is apparently due to a superiority of the direction = to that of +.

4826. The first six observations of A = 1580
The six of B = 1495
" C = 1463
" D = 1401

The average loss during five observations at any one side is 200; the average loss for the six observations may therefore be taken as 240, and $\frac{1}{4}$, $\frac{2}{4}$ and $\frac{3}{4}$ being added to B, C and D, and the sums divided by 6, will give estimates of the Specific inductive capacity corresponding to these faces and directions. These are

for = when C is to inductric ball–263·8 }
= " A " " 263·3 } = 263·5 for =.
+ " D " " 263·5 }
+ " B " " 259·1 } = 261·3 for +.

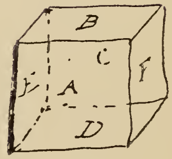
4827. This cube therefore gives but a small difference between = and + as compared to the former; still, it is in the same direction.

4828. Then compared direction AC and EF of same cube, the face B being upwards. I began also for change with the face F.

F	A	E	C
455			
	430		
		417	
			393
377			
	357		
		330	
			321
312			
	291		
		280	
			266
256			
	242		
		235	
			224

balls 380°

No. 4 cube.
Rock crystal.



F	A	E	C
218			
	206		
		198	
			189
181			
	175		
		171	
			165
155			
147			
143			
139			

4829. All the intervals are descending, though in variable proportions.

4830. The 12 intervals from + to = give an average fall of 14°·2. The 12 intervals from = to + give an average fall of 10°·7.

4831. Here therefore, the + direction EF is *better* than the = direction AC.

4832. The first six observations of F make 1799
,, ,, A ,, 1701 + 70 = 1771
,, ,, E ,, 1631 + 140 = 1771
,, ,, C ,, 1558 + 210 = 1768

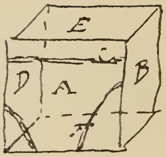
The average loss during five observations of each side is 250, so that 280 may be taken as the loss for the six observations—of this $\frac{1}{4}$, $\frac{2}{4}$ and $\frac{3}{4}$ added to A, E and C as in former cases, and the sums divided by six, will give

for = when A is to inductric ball—295·1 } = 294·8 for =.
= ,, C ,, ,, 294·6 }
+ ,, F ,, ,, 299·8 } = 297·4 for +.
+ ,, E ,, ,, 295·1 }

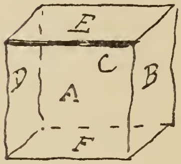
4833. Thus with this cube of Rock crystal, it appears that
+ direction FE has greatest spec. inductive capacity.
= ,, AC has next greatest ,, ,,
+ ,, BD has least inductive capacity;
but the difference is [in] no case striking or remarkable in quantity. Still, it is so as to direction, when compared with former results of the same cube.

4834. Compared the dimensions of the Rock crystal cubes Nos. 2 and 4 carefully. There is a little variation and the faces are not quite parallel, but it so happens that the dimensions in the line of the optic axis [are] in both cases *larger* than in the other directions. So that the differences are not due to any deficiency of bulk in that direction.

4835. Of No. 2 cube, the thickness from A to C is greatest,
" " B to D is a very little less,
" " E to F is smallest;
the direction =, AC, has much the greatest capacity,
" " +, EF, is rather better than BD,
" " +, DB, is rather less than EF.
The difference of the two latter corresponds with the difference in their dimensions.



4836. Of No. 4 cube, the thickness from A to C decidedly largest.
E to F a little less,
B to D a little less still;
but direction =, AC, has a capacity between the other two,
+, EF, having the greatest capacity,
+, BD, the least capacity—though of the smallest dimension.

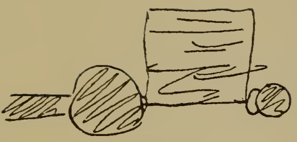


4837. As to the cause of the differences, other than crystalline structure; there may be minute fissures in the crystals, but the action of light does not point them out; or the crystallization may be irregular; or the substance not pure: and here consider how minute a quantity of matter will alter the conducting power of water; so if a little in one corner of a cube, it may affect that corner and explain not merely differences of force in the directions but even in the faces.

4838. It is quite necessary to make the connexion between the jars and their rods, etc. and also between the rods and the inductric cylinder and jar, very perfect; otherwise small differences exist to different extent at different times, and the inductric ball is not kept in one steady falling state, but varies by fits and starts. The lacquering of the rods is very dangerous under such circumstances.

4839. On the whole, it is perhaps best to separate the battery from the Machine when it is once charged. Do so in future.

4840. Is perhaps also well to have repelled ball of Electrometer charged rather highly, so that in fact the indication of (balls) may be much higher than that given by the first observation with the cube. May then keep the inductric ball low, and have less loss there.



4841. It is very easy with cubes of different substances to observe the difference of Specific inductive capacity. Thus when the Cube of Rock crystal No. 4 was in use, the induction through it (from A to C) was 223, but when it was moved to one side so far that its vertical side was in the line joining the inductric and inducteous balls, thus, then the inductive force acquired by the carrier was only 191°.

4842. In another case, with the same cube, the numbers were thus*.

4843. By using a plate with a straight edge and inducing first through the middle and then the edge of the plate, and several times in succession, probably very good results might be obtained.

4844. Thus the mean of 139 and 121 gives 130° as the induction when all the space was crystal *for the moment* when only one half was crystal and the other air. For the half of crystal therefore $\frac{130°}{2} = 65°$ may be taken, and that subtracted from 98° leaves 33° for the effect of the Air—which would make the power of crystal nearly twice that of air.

4845. Of course it is not exact, for the one half of crystal will do more than each of the two halves of crystal, because the inductive ball is not raised to so high a degree in the former as in the latter case. But the advantage of making the cube the measure of the distance and also that of keeping the inductric ball at the same tension by the battery, whatever the inducteous ball is, are important.

14 AUG. 1838.

4846. To-day worked again with the cube No. 3 of Iceland Spar.

4847. Found it a great improvement to separate the battery with its Inductric ball from the machine after charging. There is much less dissipation of electricity. Is also very important to have all the metallic connections quite perfect.

4848. Found it also important to see that repelled ball of Electro-

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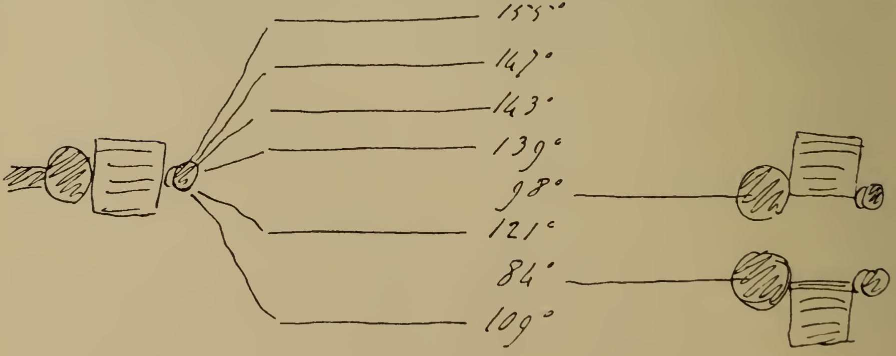
* [4842]



meter had no loose cotton hairs upon it. In gilding, it is better to use a silk handkerchief to lay the gold, for if cotton wool is used, some of the hairs adhere and then these rise up from time to time and cause great irregularity of dissipation. Has been a serious evil now and then.

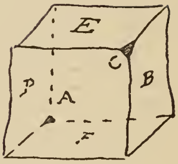
4849. The cube No. 3 was used, comparing = and + on the faces B, C, D, A. The face E of the cube was upwards. The results are tabulated on the next page[1].

4850.

+ B	= C	+ D	= A
187			
	179		
		188	
			179
173			
	176		
		174	
			169
169			
	166		
		169	
			164
160			
	158		
		157	
			157
157			
	154		
		154	
			150
147			
	147		
		147	
			143
144			

balls 340°

Iceland Spar,
No. 3.



4851. There are four risings; they are [illegible] small; but most from = to +.

4852. The 12 intervals from + to = give an average of 3·3 fall for each interval. The 12 intervals from = to + give an average of 0·25 fall for each interval. So that + seems slightly to possess the advantage over =.

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[1] Par. 4850.

4853. The six first observations of B are 993 | + 993
" " C " 980 | + 11 = 991
" " D " 989 | + 22 = 1011
" " A " 962 | + 33 = 995

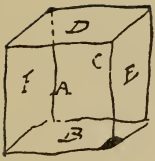
The average loss is 37·25 for $\frac{5}{6}$ of the time, and therefore about 44 for the whole time—adding then $\frac{1}{4}$, $\frac{2}{4}$ and $\frac{3}{4}$ to C, B [? D] and A and dividing by 6, it gives the inductive force for the directions as follows:

= when A is to the inductric ball as 165·5 } 165·3
= " C " " 165·1 }
+ " B " " 168·5 } 167·1
+ " D " " 165·8 }

4854. The average of A, C gives 992 for inductive capacity of direction
" B, D " 1003 " "

Here therefore, = less capacity than +.

4855. The next experiments were on faces A, E, C, F with the face D upwards.



=	+	=	+	balls 420°
A	E	C	F	
306				
	312			
		305		
			304	
303				
	302			
		291		
			295	
287				
	292			
		281		
			274	
276				
	286			
		271		
			273	
265				
	267			
		256		
			258	
257				
	265			
		255		
			252	
248				

Iceland Spar,
No. 3.

4856. There are 8 risings from = to +, and only 1 from + to =.

The 12 intervals from = to + give an average rise of 2·4 for each. The 12 intervals from + to = give an average fall of 7 for each. Here therefore the + direction appears to have decidedly the greatest inductive capacity.

4857. The six first observations of A make 1694 . . . 1694
" " E " 1724 + 14·75 = 1738
" " C " 1659 + 29·5 = 1688
" " F " 1656 + 44·25 = 1700

The average loss for five observations is 49·5, and therefore for the time of the six observations 59 about. Of this, $\frac{1}{4}$, $\frac{2}{4}$ and $\frac{3}{4}$ added to E, C and F, and then dividing by Six will give for

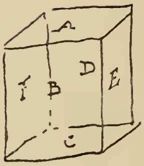
$$\left.\begin{array}{lr} = \text{A is to inductric ball} - & 282{\cdot}3 \\ = \text{C} \quad " \quad " & 281{\cdot}3 \end{array}\right\} = 281{\cdot}8 \text{ for } =.$$

$$\left.\begin{array}{lr} + \text{E} \quad " \quad " & 289{\cdot}6 \\ + \text{F} \quad " \quad " & 283{\cdot}3 \end{array}\right\} = 286{\cdot}4 \text{ for } +.$$

4858. Thus = falls short of +, and E and F both differ much from each other.

4859. The next experiments were with faces B, E, D, F of the same cube No. 3, the face A being upwards.

B	E	D	F	balls 470°
360				
	350			
		349		
			338	Iceland Spar,
335				No. 3 cube.
	343			
		330		
			327	
327				
	327			
		325		
			322	
317				
	315			
		311		
			308	
313				
	307			
		300		
			303	
303				
	303			
		297		
			299	
295				



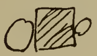
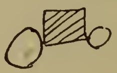
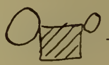
4860. There are rising[s] both in passing from + BD to + EF, and also in passing back from EF to BD.

4861. The 12 intervals from BD to EF give an average fall of 2°·5. The 12 intervals from EF to BD give an average fall of 2°·9.

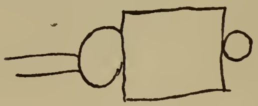
4862. The 6 first observations of B make 1955 . . . 1955
" " E " 1945 + 15 . . 1960
" " D " 1912 + 30 . . 1942
" " F " 1892 + 45 . . 1937

60 is the average loss during the six observations on each face. Adding then $\frac{1}{4}$, $\frac{2}{4}$ and $\frac{3}{4}$ to E, D and F and dividing by 6 it gives
for + when B is to the inductric ball 326
+ " E " " 326·6 = 324·8
+ " D " " 323·6 = 324·7
+ " F " " 322·8

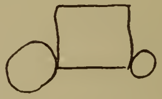
4863. So the two directions seem here to be very nearly equal to each other.

4864. Now tried a few experiments, sometimes with the cube thus  –and then again thus  or thus  – ( ).

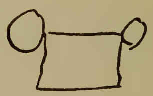
4865. First with Cube No. 3 of Calc. Spar, with face A upwards and face B to the inductric ball–the lines of inductive action being therefore along + BD.



. . 295



. . . . 235°
. . . . 235°
. . 288°
. . 287°

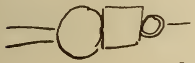


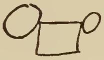
. . . . 230
. . . . 231
. . 285°
. . 285°

4866. With cube equally placed, the average is 288. With cube half placed the average is 232·75. The difference 55·25 doubled may be supposed to give the loss which would have happened had the cube been entirely away, = 110·5, and this subtracted from 288 gives the inductive force in air = 177·5. Hence the inductive forces would appear to be in Calc. Spar, for this direction of + BD,

4867. for Air . . 117·5 } or { 1
,, Spar . . 288 } or { 1·622

4868. Then took Cube No. 1, or the first calc. spar cube, but it is evidently much too small for the inductric and inducteous balls used. However, face E was upwards, face C to the inductric ball.



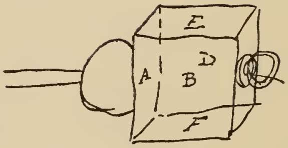
. . 133°
. . 133°
. . . .  . 117

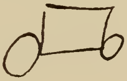
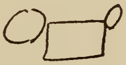
4869. The difference 16° being doubled = 32°, and subtracted from 133° gives 101° as the force in air. Hence

In air . . . 101 or 1
in spar . . . 133 ,, 1·31

but cube far too small to give full effect of calcareous spar. Part of the induction was through the air around it.

4870. Now used the Rock crystal cube No. 2—side E being upwards, and the face A to the Inductric ball. No. 2 cube.

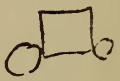


4871. . . 137
. . 138
. . . .  . 124
. . . . 120
. . 138
. . . .  . 127
. . . . 121
. . . . 120
. . 134
. . 134

4872. The average for central cube is 136·2. The average for the half positions is 122·4. The difference 13·8, doubled and subtracted from 136·2, gives 108·6 as the force for air.

4873. So Air . . . 108·6 or 1
Rock crystal . 136·2 or 1·254

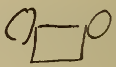
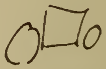
4874. Cube No. 4, Rock crystal, face E upwards, C being towards the Inductric ball.

. . 341
. . 332
. . 343
. . . .  . 274
. . . . 276
. . 330

4875. The average for the central cube is 336·5—and for the half positions 275. The difference, 61·5, doubled and subtracted from 336·5, gives 213·5 as the force through air; thus

4876. Air . . . . 213·5 or 1
R. Crystal . . 336·5 „ 1·575

4877. Again, with the same cube and faces, i.e. in the direction CA.

4878. . . . .  . 333
. . . . 325
. . 367
. . 358
. . . . 323
. . . .  . 292

4879. Here are irregularities—but taking the 2nd, 3rd, 4th and 5th observations, the average for the central cube is 362·5 and for the half positions 324. The difference, 38·5, doubled and subtracted from 362·5 gives for

4880. Air . . . . 285·5 or 1
R. crystal . . 362·5 „ 1·27

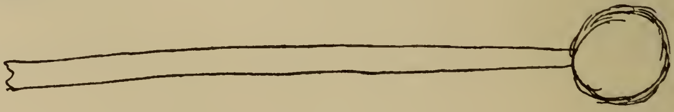
4881. Must try all these expts. again with larger plates of dielectric—and also have a perfect surface to the repelled ball of the Electrometer, etc.

4882*. The diameter of the Inductric ball used in all these experiments was 0·73 of an inch.

4883. I must try several cubes, central and halved.

4884. Must also try Cube No. 2 + and = with air, i.e. central and halved.

* [4882]



4885.		= AC	+ BD	+ EF	= A	= C	+ B	+ D	+ E	+ F
R.C. No. 2	22 June (4695)	110·11 *100*[1]	103·4 *93·9*							
R.C. No. 2	25 June (4702)	132 *100*		119·5 *90·53*	131·5 *99·62*	132·6 *100·4*			118·8 *90*	120·3 *91·13*
R.C. No. 2	25 June (4707)		121·8 *93·59*	120·5 *92·59*			120·8 *92·82*	122·8 *94·36*	120 *92·20*	121 *92·97*
I.S. No. 1	25 June (4713)	146·8 *100*	145·5 *99·11*		146·8 *100*	146·8 *100*	145·5 *99·11*	145·5 *99·11*		
I.S. No. 1	25 June (4716)	121·7 *100*		119·25 *97·98*	122 *100·24*	120·5 *99*			117·75 *96·75*	120·75 *99·22*
I.S. No. 1	25 June (4718)		244·3 *98·66*	226·8 *91·59*			244 *98·54*	244·6 *98·78*	228·6 *92·32*	225 *90·86*
I.S. No. 1	25 June (4720)		236·9 *98·66*	225·1 *93·74*			236·6 *98·53*	237·3 *98·82*	222·8 *92·78*	227·5 *94·74*
I.S. No. 1	25 June (4728)	257 *100*	252·4 *98·21*		254 *98·83*	260 *101·17*	252·8 *98·36*	252 *98·05*		
I.S. No. 1	25 June (4732)	235·8 *100*		235 *99·65*	234 *99·23*	237·6 *100·76*			237·6 *100·76*	232·4 *98·56*
I.S. No. 3	6 Aug. (4750)	378·3 *100*	387·3 *102·38*		370·6 *98*	386 *102·03*	385·2 *101·82*	389·4 *102·93*		
I.S. No. 3	6 Aug. (4755)	176·3 *100*		180·3 *102·27*	176·1 *99·9*	176·6 *100·17*			180·1 *102·15*	180·6 *102·43*
R.C. No. 4	6 Aug. (4760)	323·9 *100*	317·6 *98·05*		325·8 *100·58*	322·8 *99·66*	311·6 *96·2*	323·5 *99·87*		
R.C. No. 4	6 Aug. (4768)	152·2 *100*		151·3 *99·4*	150·1 *98·62*	154·1 *101·24*			149·5 *98·22*	153·1 *100·59*
R.C. No. 2	8 Aug. (4798)	210·7 *100*	198·8 *94·35*		214·4 *101·75*	207 *98·28*	200·4 *95·11*	197·3 *93·64*		
R.C. No. 2	9 Aug. (4786^x)	330·9 *100*	310·0 *93·68*		332·7 *100·54*	329·1 *99·45*	314·2 *94·95*	305·8 *92·41*		
R.C. No. 2	9 Aug. (4792^x)	263·1 *100*	243·2 *92·43*		262·1 *99·62*	264·1 *100·38*	244·8 *93·08*	241·6 *91·83*		
R.C. No. 2	9 Aug. (4799^x)	364·6 *100*		342·7 *94·0*	367·7 *100·85*	361·5 *99·15*			344·1 *94·37*	341·4 *93·63*
R.C. No. 2	9 Aug. (4803)	312·1 *100*		294·3 *94·29*	306·2 *98·12*	318·0 *101·89*			293·2 *93·94*	295·5 *94·68*
R.C. No. 2	9 Aug. (4804)	332·8 *100*		312·6 *93·93*	331·1 *99·48*	334·5 *100·51*			313·1 *94·08*	312·2 *93·81*
R.C. No. 2	9 Aug. (4807)		227·1 *93·59*	229·3 *94·54*			230·5 *95·0*	223·7 *92·19*	230·8 *95·11*	227·8 *93·87*
R.C. No. 4	9 Aug. (4817)		351·6 *98·6*	354·7 *99·47*			343·2 *96·24*	359·5 *100·81*	349·7 *98·06*	359·7 *100·87*
R.C. No. 4	11 Aug. (4823)	263·5 *100*	261·3 *99·16*		263·3 *99·92*	263·8 *100·11*	259·1 *98·33*	263·5 *100*		
R.C. No. 4	11 Aug. (4828)	294·8 *100*		297·4 *100·88*	295·1 *100·1*	294·6 *99·93*			295·1 *100·1*	299·8 *101·7*
I.S. No. 3	14 Aug. (4850)	165·3 *100*	167·1 *101·09*		165·5 *100·12*	165·1 *99·88*	168·5 *101·93*	165·8 *100·3*		
I.S. No. 3	14 Aug. (4855)	281·8 *100*		286·4 *101·63*	282·3 *100·17*	281·3 *99·82*			289·6 *102·77*	283·3 *100·53*
I.S. No. 3	14 Aug. (4859)		324·8 *101·73*	324·7 *101·69*			326 *102·1*	323·6 *101·35*	326·6 *102·29*	322·8 *101·1*

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[1] Numbers in Italics are in red ink in the MS.

		=	+	+	=	=	+	+	+	+
		AC	BD	EF	A	C	B	D	E	F
ROCK CRYSTAL CUBE NO. 2	(4695)	110·11	103·4							
	(4798)	210·7	198·8		214·4	207	200·4	197·3		
	(4786^{x})	330·9	310·0		332·7	329·1	314·2	305·8		
	(4792^{x})	263·1	243·2		262·1	264·1	244·8	241·6		
	(4702)	132		119·5	131·5	132·6			118·8	120·3
	(4799^{x})	364·6		342·7	367·7	361·5			344·1	341·4
	(4803)	312·1		294·3	306·2	318·0			293·2	295·5
	(4804)	332·8		312·6	331·1	334·5			313·1	312·2
	(4707)		121·8	120·5			120·8	122·8	120	121
	(4807)		227·1	229·3			230·5	223·7	230·8	227·8
ROCK CRYSTAL CUBE NO. 4	(4760)	323·9	317·6		325·8	322·8	311·6	323·5		
	(4823)	263·5	261·3		263·3	263·8	259·1	263·5		
	(4768)	152·2		151·3	150·1	154·1			149·5	153·1
	(4828)	294·8		297·4	295·1	294·6			295·1	299·8
	(4817)		351·6	354·7			343·2	359·5	349·7	359·7
ICELAND SPAR CUBE NO. 1	(4713)	146·8	145·5		146·8	146·8	145·5	145·5		
	(4728)	257	252·4		254	260	252·8	252		
	(4716)	121·7		119·25	122	120·5			117·75	120·75
	(4732)	235·8		235	234	237·6			237·6	232·4
	(4718)		244·3	226·8			244	244·6	228·6	225
	(4720)		236·9	225·1			236·6	237·3	222·8	227·5
ICELAND SPAR CUBE NO. 3	(4750)	378·3	387·3		370·6	386	385·2	389·4		
	(4850)	165·3	167·1		165·5	165·1	168·5	165·8		
	(4755)	176·3		180·3	176·1	176·6			180·1	180·6
	(4855)	281·8		286·4	282·3	281·3			289·6	283·3
	(4859)		324·8	324·7			326	323·6	326·6	322·8

	= AC	+ BD	+ EF	= A	= C	+ B	+ D	+ E	+ F
(4695)	*100*[1]	*93·9*							
(4798)	*100*	*94·35*		*101·75*	*98·28*	*95·11*	*93·64*		
(4786^{x})	*100*	*93·68*		*100·54*	*99·45*	*94·95*	*92·41*		
(4792^{x})	*100*	*92·43*		*99·62*	*100·38*	*93·08*	*91·83*		
(4702)	*100*		*90·53*	*99·62*	*100·4*			*90*	*91·13*
(4799^{x})	*100*		*94*	*100·85*	*99·15*			*94·37*	*93·63*
(4803)	*100*		*94·29*	*98·12*	*101·89*			*93·94*	*94·68*
(4804)	*100*		*93·93*	*99·48*	*100·51*			*94·08*	*93·81*
(4707)		*93·59*	*92·59*			*92·82*	*94·36*	*92·20*	*92·97*
(4807)		*93·59*	*94·54*			*95·00*	*92·19*	*95·11*	*93·87*
	100	93·59	93·31	99·99	100	94·19	92·88	93·28	93·34[2]
(4760)	*100*	*98·05*		*100·58*	*99·66*	*96·2*	*99·87*		
(4823)	*100*	*99·16*		*99·92*	*100·11*	*98·33*	*100*		
(4768)	*100*		*99·4*	*98·62*	*101·24*			*98·22*	*100·59*
(4828)	*100*		*100·88*	*100·1*	*99·93*			*100·1*	*101·7*
(4817)		*98·6*	*99·47*			*96·24*	*100·81*	*98·06*	*100·87*
	100	98·60	99·92	99·80	100·23	96·92	100·23	98·79	101·05[2]
(4713)	*100*	*99·11*		*100*	*100*	*99·11*	*99·11*		
(4728)	*100*	*98·21*		*98·83*	*101·17*	*98·36*	*98·05*		
(4716)	*100*		*97·98*	*100·24*	*99*			*96·75*	*99·22*
(4732)	*100*		*99·65*	*99·23*	*100·76*			*100·76*	*98·56*
(4718)		*98·66*	*91·59*			*98·54*	*98·78*	*92·32*	*90·86*
(4720)		*98·66*	*93·74*			*98·53*	*98·82*	*92·78*	*94·74*
	100	98·66	95·74	99·57	100·23	98·63	98·69	95·65	95·84[2]
(4750)	*100*	*102·38*		*98*	*102·03*	*101·82*	*102·93*		
(4850)	*100*	*101·09*		*100·12*	*99·88*	*101·93*	*100·3*		
(4755)	*100*		*102·27*	*99·9*	*100·17*			*102·15*	*102·43*
(4855)	*100*		*101·63*	*100·17*	*99·82*			*102·77*	*100·53*
(4859)		*101·73*	*101·69*			*102·1*	*101·35*	*102·29*	*101·1*
	100	101·73	101·86	99·54	100·22	101·95	101·53	102·40	101·35[2]

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[1] Numbers in Italics are in red ink in the MS.

[2] These lines are in pencil in the MS.

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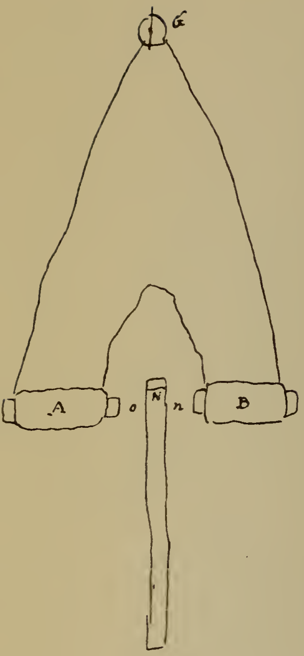
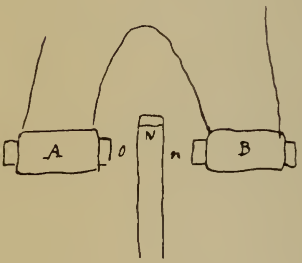
4886. Expts. on interposition of different dielectrics across the course of the Magnetic curves.



4887. A and B are two helices with iron cores, N the north pole of a bar magnet placed between, G is a galvanometer—very delicate. A and B are so arranged that as the magnet moves from one to the other, by a little lateral displacement, the currents formed in them shall coincide, i.e. that as it moves from B and towards A, the current occasioned by the falling of the mag. forced in B and that occasioned by the rising of the Mag. force in A shall accord and join in their effect to influence the galvanometer needle.

4888. A pendulum was arranged to vibrate isochronously with the needle of the galvanometer. The interval between the Magnetic bar N and each of the iron cores was about $1\frac{1}{2}$ inches. The motion of the mag. pole isochronously with this pendulum and to not more than the eight[h] of an inch to and fro between the two helices, i.e. from one towards the other and back again, quickly deflected the Galvanometer needle considerably. Hence but little weakening of the effect on one helix, conjoined with a little strengthening on the other, was quite sufficient to produce a sensible effect.



4889. Had prepared plates of different substances for the purpose of being introduced between the Magnetic pole and the ends of the iron cores in the helices. For instance, the pendulum was set swinging—then a copper plate introduced at *n* without touching N or B, and kept there for the time during which the galvanometer needle would swing one way. It was then withdrawn for the time due to the swing the other way, introduced for an equal time, withdrawn again and so on, in hopes to accumulate any effect at the galvanometer needle.

4890. Sometimes two plates were used, one being introduced at *o* whilst that at *n* was out, and then taken away whilst that at *n* was in and so forth. Such was the general process of trial.

4891. *Copper.* Whether one or two plates were used, each being 0·7 of an inch thick, there was *no* effect at Galvanometer.

4892. *Shell lac.* One or two plates, 0·9 of inch thick, produced *no* action. Two wedge shaped plates were used to gradually change the effect of introduction; still *no action.*

4893. *Sulphur.* A plate 0·9 of inch thick; *no* action.

4894. A plate of *iron*, though thin, caused great action; a small piece, as a key, also caused action readily. This was by diverting part of the Mag. force of the bar from off the helix cores, but still shews the sensibility of the apparatus to the other kind of action sought for.

4895. It is possible, however, that different results may be obtained when the iron cores are away—for the extra action of iron and its relation to the magnet may over rule any effect due to the variation of the force of induction of mere currents. This will be settled when simple helices shall be substituted for the core helices A and B.

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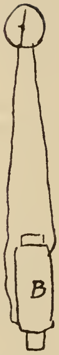
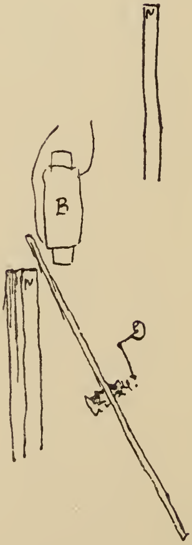


4896. Arranged the Magnet N and magneto-electric helix B thus—the Galvanometer being unaffected by moderate motions of the magnet. The arrangement was such that when the N. pole of the magnet approached the end of the core in B, the north end of the needle in the galvanometer moved westwards, and when magnet receeded from the core, the motion of that end of the needle was towards the east.



4897. Now introduced the edge of a copper disc $\frac{1}{5}$ of an inch thick between the pole and the core.

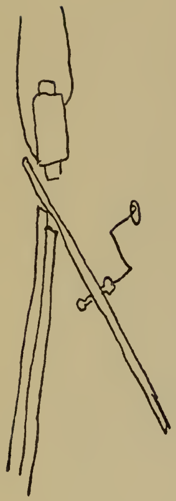
4898. Set the pendulum (   ) vibrating. Then revolved the copper disc quickly during the time occupied by the needle (when in motion) to pass in one direction—stopped the rotation for a time equal to its return—renewed it for an equal portion of time—stopped it again for an equal portion of time, and so on, for 8 or 10 alternations or more. Then examined the Galvanometer needle.

4899. At first I obtained motions in the needle corresponding to the rotation of the copper disc, but by investigation I discovered this was due to the effect of the pressure required to hold it steady whilst revolving, causing a slight bending of the table, and so altering the distance of the pole and the core in a minute degree. As this happened regularly with the vibration of the pendulum, it soon produced a sensible effect.

4900. In fact, giving the same pressure at regular periods, *without* rotating the disc, produced the deflection of the needle.

4901. This shews the delicacy of the arrangement; nevertheless it was not able to shew any effect due to the rotating copper, whether movg. one way or the other.

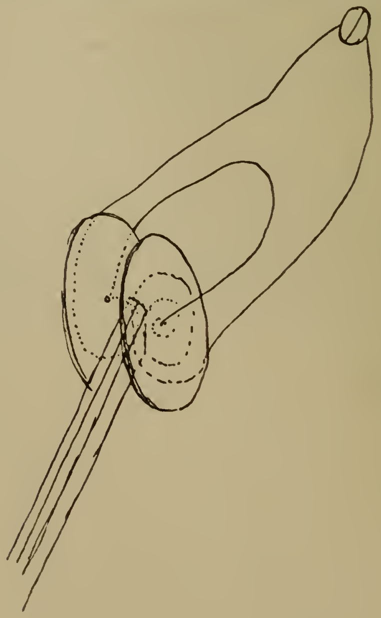
4902. Then put the copper plate oblique to the direction of the magnetic curves thus, to ascertain whether that would make a difference, but still *no effect* was produced.



4903. *Shell lac* disc 0·6 of inch in thickness, rotated in the same manners, produced *no effect.*

4904. Now used flat helices instead of the previous long helices and cores. This was for the purpose of removing the action of iron as regarded the helices. Each helix was of silked copper wire arranged on a cardboard and containing feet of wire. They were supported by feet and arranged thus*. The north pole of a magnetic bar was between them and, as they were four inches or more apart, it could be moved between them or they towards it. When the pole was withdrawn from or introduced between the flat helices equally to each, or when they were moved together from or towards the pole equally, there was no current, the tendency in the helices being contrary to each other. But when the mag. effect on one side was weakened whilst that of the other was strengthened, then the currents produced in both helices combined to influence the galvanometer. So if the pole were moved *from* one helix *towards* the other, a strong current was at once produced. Or when the helices, always kept at the same

* [4904]



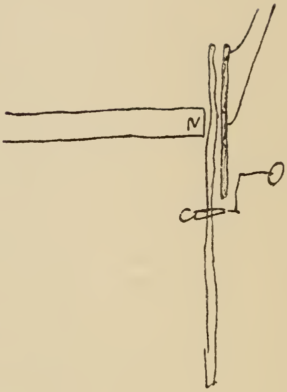
distance from each other, were moved together to the right or left, then a strong current was produced.

4905. *Shell lac.* Then used two plates of shell lac as before with the Mag. Electric helices and cores ( ), but there was *no action.*

4906. *Sulphur.* The plate of this substance employed in the same way. *No action.*

4907. *Copper.* The thick plates employed as before; *no action.*

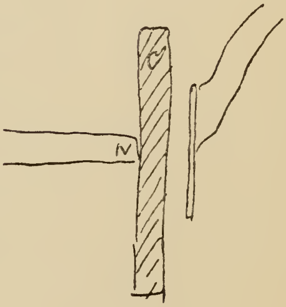
4908. Used one of the flat Helices, the North pole of the magnet and the revolving copper plate thus, but the copper acquired no power of varying the effect by revolution. Whether moving or quiescent, it was equally indifferent.



4909. *Shell lac.* Made a similar adjustment with the revolving shell lac, but it was equally ineffective.

4910. Now made this experiment. Placed a helix and a magnetic pole thus*. On moving the helix to and fro[m] the pole in accordance with the vibrations of the pendulum, currents in its wire were quickly formed and shewn by the galvanometer.

4911. Put a thick plate of copper C against the magnetic pole, between it and the helix: then moving the helix to and fro, currents were produced, just as easily and in the same direction as before, though the copper was half an inch thick.



4912. With the same arrangement, made the helix stationary and moved the magnet to and fro; the effect was the same and as ready as before. Whenever the interval between the magnet and helix was increased, a current was formed in the latter, which was the same whether it was the helix or magnet which moved; and so also when the distance was diminished.

4913. This is a very striking and important result.

4914. When a thick plate of *sulphur* was in place of the *copper*, the effects were exactly the same.

4915. I do not think the intervening bodies have any effect on the magnetic influence, whether they are in motion or at rest.

4916†. Put the case thus. If a wire *n* have a current suddenly sent through it, it tends to and will produce a contrary current in the wire *o*; but suppose a thick copper rod *p*, in form of a ring, put on its other side, will not that divert some of the force of *n* from *o*? *n* and *o* may be two helices and *p* a thick block of copper between.

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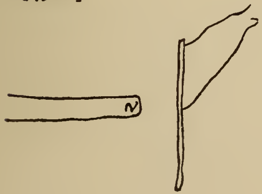
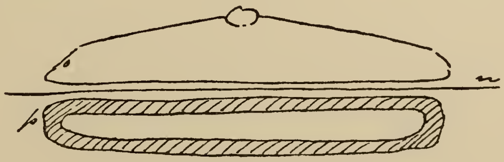
* [4910]



† [4916]



4917. If it does, it will shew that neighbouring matter has its influence. If it does not, it will go greatly to shew that Electl. and Magnetic action are essentially different in their nature.

4918. Must there not be *some* effect on non-conductors, lateral to a wire carrying a current, correspondent to the effect on conductors? Or is the action really a distant one and only on like matter or on like kind of power? It may be so.

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4919. The strange case of diamond and carbon, as well as those of tourmaline and boracite, makes one look for something in crystalline structure.

4920. Crystd. metals together in different directions heated perhaps give currents.

4921. Crystals of conducting minerals, haematite, Elba iron, Antimony, etc.

4922. Perhaps Mica a good dielectric across its plate because that direction coincides with the optic axis.

4923. Try cubes of sulphur and shell lac, on faces A, B, C, D, etc.

4924. Excite one face of lac or sulphur cube first—then try the effect.

4925. Bismuth point drawn over Bismuth plate: will it give an electric current?

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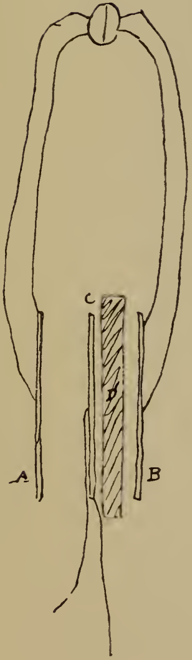


4926. Used three helices and a double galvanometer, i.e. a galvanometer having two wires each 42 feet long, wound together on one frame, so that separate currents could be sent through them—found by trial that there was no connection between the two wires; each was independant of the other.

4927. The coils were arranged parallel to each other and about 1 inch apart. The outer coils were connected each with one of the wires of the galvanometer, and the middle coil was connected with a V. battery, so that contact could be made or broken at pleasure.

4928. It was ascertained first that when only coil A or coil B was influenced by coil C, that either making or breaking contact powerfully affected the galvanometer. But then the distances were adjusted so that the action of the two, being in contrary directions at the galvanometer, no effect was produced there. At that moment two opposite current[s] were produced but exactly equal in effect.

4929. Put a copper plate D, 6 inches square and 0·6 of an inch in thickness, between B and C, and then made and broke contact as before. This caused not the slightest difference in the action of C on A and B. Placed it between A and C; still no difference.

4930. Used a plate of sulphur 0·9 of an inch thick; still not the smallest effect.

4931. Hence these interposed bodies do not in any way interfere with the action, and that is very strange.

4932. The only difference that could escape me might be one of time. The action might be quicker or slower through copper, air, sulphur, etc.; and yet the sum of action being the same and the time of vibration long, the result might be the same on the instrument.

4933. I was puzzled a little at first by the needles changing their magnetic state. But I soon found that the induced current was able to give a magnetic charge or destroy it very easily on such masses of steel as these small needles.

4934. The proof of non action of intermediate matter is not as yet sufficient; for the effects of currents produced in copper and non magnetic metals interfere. These being connected in all things with nonconductors, as for instance in their contrasted state in the induction by magnets, referred to in series (213).

4935. In considering the induction of *currents*, remember the circumferential effect cannot be disturbed in degree, i.e. no power can be drawn from the left of a wire carrying a current by any thing, as copper, or any action, present or exerted on the right. Such is not the case in the induction of Static electricity. Nor is it the case with Magnetic forces exerted as poles. Must consider and relate this.

4936. At the Adelaide Gallery, to make a few experiments with the Gymnotus there. Present Mr Bradley, Mr Watkins and Mr .

4937. The Gymnotus was brought to this country about 4 weeks ago. It is about 3 feet 6 inches in length; is in a round large tub of warm water (at 74°–78°) with some sand at the bottom—has not fed whilst here or on the passage to this country, and is probably very languid, though he gives good shocks when one's hands are well disposed.

4938. I had a few shocks some days ago, and then, as now, found that when one hand or arm was put into the water (which was not above 8 inches deep), the electric shock was comparitively trifling.

4939. Whether the hand was at the head or towards the tail, shocks could be obtained, but strongest about the neck, and then at a part extending from six inches from the tail to the middle of the body.

4940. *Only the part in the water was affected.* If the hand merely was in, the shock was very slight and pricking in the joints. When the hand and part of the arm was in, it was better, and especially if the direction of the hand and arm was coincident with the direction of the fish.

4941. Whether the hand was on the back or the belly of the fish, made no sensible difference.

4942. On putting the two hands into the water, if they were both applied to the same part of the fish, or to the top and bottom at the same part of the fish as to length, the shock was trifling just as before with one hand, and did not reach out of the water, and this whatever part of the fish, as head or tail, they were applied to.

4943. But on separating the hands in the direction of the fishes body, then shocks out of the water were felt. Thus with one hand towards the head and the other towards the tail, very powerful shocks were given. When two of us joined hands to make one circuit, both were strongly affected in this manner.

4944. As the hands came nearer together, or as the line joining them approached more towards that which was vertical to the fishe's body, the shocks became less and less until they resumed the former character and did not extend to the parts out of the water.

4945. It was evident that the shock was strongest from the head to the tail. All the experiments tended to shew that the part towards the head was in the state of one end of a voltaic battery or one side of a Leyden arrangement, and the part towards the tail in the opposite state. Every thing accorded with this view.

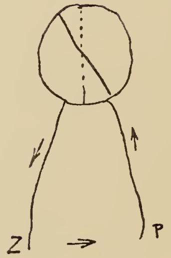
4946. I never obtained a shock with either one or two hands, without touching the fish. At the same time, if the hand towards the head touched the fish, a strong shock was obtained when the hand towards the tail was not in contact by 2, 3 or 4 inches.

4947. I doubt not the fish could give shocks without either hand touching the fish, if he were so disposed by any circumstance.

4948. I do not believe the fish knows whether his shock is effectual, or whether it is felt much or little. I think that at all times when he shocks, he sends a great force of current through the water around him, which the experimenter is not sensible of.

4949. To-day, we endeavd. to determine the direction of the current external to the fish.

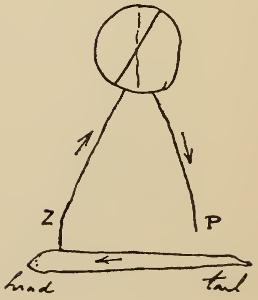
4950. We had a galvanometer which, when the wire Z had a piece of Zinc attached to it, and the wire P a piece of platina, and these brought against the tongue, was deflected as in the figure. Hence such a deflection indicates an electric current in the direction of the arrows.



4951. The wires Z and P being lengthened, platina plates were made fast to both, and it was first ascertained that immersion of these in the water of the tub did not produce a current or deflect the galvanometer.

4952. These plates were then put into the water, and one being brought near the head or tail, the other was made to touch the tail or head until the fish gave the Shock.

4953. Plate P was held near the tail, and plate Z brought into *contact* with the neck. Immediately the galvanometer needle was deflected about 5° in the direction marked, shewing a current indicated in direction by the arrow heads.



4954*. Then plate P was brought near the head and plate Z made to touch the tail part. Immediately the needle was deflected as in the figure, the contrary way to the former, shewing a current as figured by the arrow.

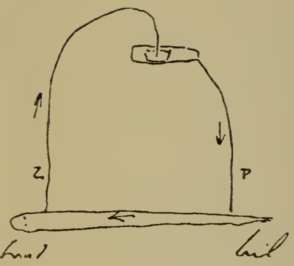
4955†. Another experiment, in which both head and tail were touched by the respective plates, and the deflection was as represented.

4956. Thus the Gymnotus can deflect the galvanometer, and the direction of the needle shews that the fore part of the fish is Positive and the posterior part negative, i.e. the current without the fish is from head to tail. Whether there is one within him from tail to head is a question to be considered.

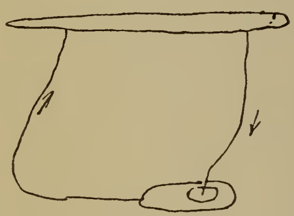
4957. The fish seems in the condition of a tourmaline.

4958. Whether the head or the tail was touched made no difference in the direction.

4959. Then tried Electrical decomposition of Iodide of potassium on paper between a plate of Platina and a wire of platina. Soon obtained abundant decomposition, and when the wires were arranged thus, iodine was evolved against the end of the wire Z, the other end being at the head of the fish. Shewing a current as figured by the arrows.



4960. Again, in another experiment the same result, still giving the same direction for the current.



4961. Other experiment[s] were of the same kind.

4962. Once or twice I thought I had decomposition when the wire from the posterior parts was on the paper, but am doubtful. Besides, if he gave a spark, that might be the case.

4963. Tried to obtain a spark with a file and a blade, but did not succeed.

4964. Thinking the fish might be fatigued, suspended all further experiment and changed his water.

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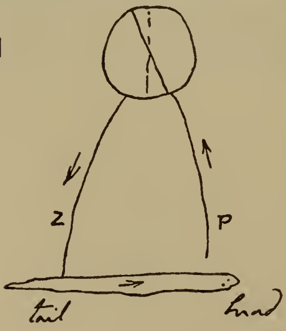
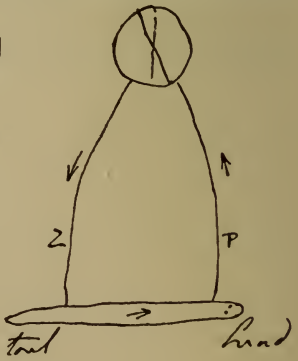
4965. The Gymnotus appears to be in good health still, but does not feed. Some blood is put into his water over night and left in until the next morning, when the water is changed for fresh.

* [4954]



† [4955]



He has small gravel at the bottom of his tub, and looks very well indeed in the clear water, which can now be retained in that state. He seems active and in good health. The eye which was injured is lost but the wound healed.

4966. When touching him at the neck only with one hand, I did not feel a shock. But when the other hand was also at the body lower down, six inches or more, then had the shock powerfully.

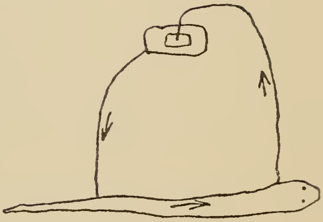
4967. I put one hand near to but not touching at the neck, and the other near to but not touching near the tale. Mr Gassiot (who with Mr Bradley were present), then touched the fish with a glass rod, and after a few moments he gave me a strong shock though I was not touching him.

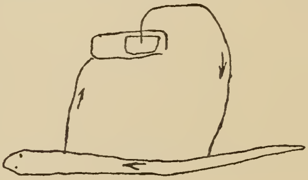
4968. Sometimes his shocks are double or triple, i.e. two or three in very rapid succession. This is an important fact. It was so in this case.

4969. We now proceeded to ascertain the chemical action, using the same plates and wires of platina as before. Beautiful results were at once obtained. Thus, when the platina wire belonging to the plate near his head rested at the other extremity on paper dipped in solution of iodide potassium, decomposition was obtained on irritating the fish, and iodine evolved against the end of that wire.

4970. When that wire was made to touch at the part towds. the tail, there was no evolution of iodine against it.

4971. When the first arrangement was restored, there was again decomposition against the end of the wire and iodine evolved there.

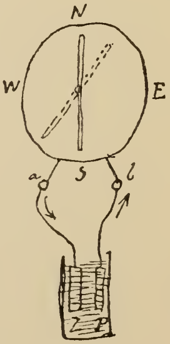


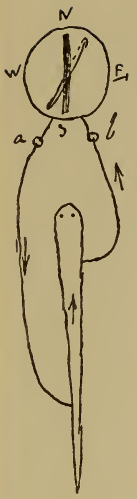


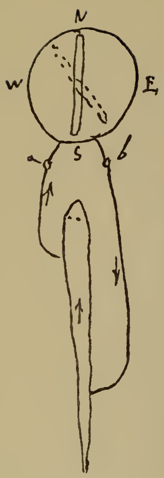
4972. These results agree with the former and give the course of the current from the anterior to the posterior parts of the fish, *out of his body*. The fore parts are positive, the hind parts negative.

4973. Now made galvanometrical experiments. The galvanometer was the same as before. When zinc was connected with *a* and platina with *b*, the North end of the needle was deflected to the east. Such deflection therefore shews a current going through the galvanometer wire from *b* to *a*.

4974. After a few trials, obtained two beautiful results, in which the Platina plates in the water were brought into good contact with the body of the fish, and he fairly touched and excited.







4975. In the first, the wire from *a* was made to touch near the tail on the left side of the fish, and the wire from *b* made to touch near the head on the right side. On touching the fish, at first all was quiet, and then suddenly the needle started off, the north end full 30° to the east, indicating a current and a very powerful one from the head of the fish through the instrument towards the tail.

4976. The expt. was repeated, but now the wire from *a* touched the fore part on the left side, and the wire from *b* the hinder part on the right side. After a moment or two, the fish gave forth his power, the needle was strongly deflected full 30° to the W. at the north end, shewing a current as before from the anterior to the posterior parts *external* to the fish.

4977. I think the fish knows when he shocks a thing that can feel; the mechanical spasm caused in them being probably the indication to him. If touched by my two hands, he will give shock after shock, but if touched by things that remain quiescent under the shock, he remains himself quiet or requires much more stimulating.

1838. 15 SEPTR.

4978. This evng. at 9 o'clk. There was a fine Aurora borealis at Brighton, where I saw it. Streamers—much general light in the N.W. and two strong streaks or streams in the sky in S.W., high up. All these streams pointed not to the Zenith, but to a point 20° or more S.E. of the Zenith.

4979. There had been Aurora two nights before, but I did not see it.

16 SEPTR.

4980. Aurora again at Brighton on the evng. of this day, Sunday: was as a strong general light.

OCTR. 1838.

4981. Marianini has a clever paper on my chem. proofs of theory of Voltaic pile. I am reading it and think I see the way through it. It is probably so important as to deserve an answer; I mean that the answer may be made not merely controversial but a real elucidation of the subject. Mem. dell. Soc. Ital. di Scienza di Modena, xxi, 205.

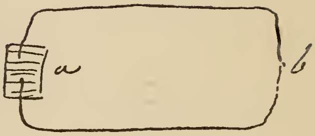
4982. In that case, in answer to the first part, shew that Electrolyte opposes its chem. affinity force to the current and make the difference.

4983. Shew power of retardation by a reversed pair, using a voltameter instead of a galvanometer.

4984. Investigate retardation of a *metal contact current* by an interposed electrolyte; using for that purpose a thermo electric current able to deflect a certain No. of degrees.

4985. If Marianini might say that this current is not so intense or powerful as a metallic contact current. Pray why not?

4986. Put at *a* the Nitro sulc. acid motor, and at *b* first hydriodate of potassa—then metallic contact; and observe the relative results. Then put at *a* a thermo electric motor and at *b* as before. If metallic contact at *a* is so effective at *b* in the latter case, why not in the former?



4987. Can make *b* a metallic contact which, according to Marianini, ought to give a current one way or the other; yet in connection with the following expts. on sulphurets, it does not matter which way it is.

As to *Sulphuret of potash.*

4988. Why does not Sulrt. of copper, according to Marianini, form a current after it is made as well as *during* making; if not chemical? Try sulphur with other metals.

4989. Try to obtain currents with ready made sulphurets of copper and Iron, etc. etc.; according to Marianini they should give currents without chem. action.

4990. Search for a connector which will not produce a current by contact, according to Volta, as for instance perhaps fluoride of lead—then try its thermo electric relation and try to apply it in the investigation.

4991. Search for two or three metals in which the thermo electric order and the contact order are not the same, according to Marianini or Volta. Search also for chem. order and deduce some arguments from these.

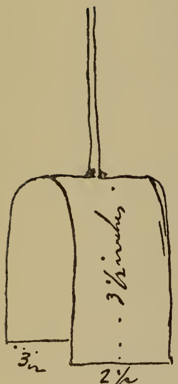
4992. If metallic contact effective, then effect should vary with quantity of surface of metallic contact, as it does with quantity of surface of acting plate.

4993. When really originating from metallic contact, as in thermo electric current, then does it not vary with size of surface of contact? Try.

OCTR. 15, 1838.

4994[*]. Made some experiments to-day with a Leyden Jar and battery in imitation of the effects of the Gymnotus. *a*, a brass ball $2\frac{1}{2}$ inches in diameter with a metal rod *c*–*b*, a brass ball $3\frac{3}{4}$ inches in diameter with a metal rod *d*. The balls were each wrapped in several folds of cloth and then tied firmly on to a board, so as to stand at the bottom of a pan of water: *e* and *f* were glass tubes passing loosely over the stems. The balls *a* and *b* were 7 inches apart. The water in the pan was $17\frac{1}{2}$ inches long: 13 inches wide and 5 inches deep. By connecting *c* with the outside of a charged jar or battery and *d* at the proper moment with the inside, then at the moment of the discharge, the electricity would pass through the water between and about *a* and *b*, and more or less resemble that passing in the water about the body of the Gymnotus.

4995. I had two electro collectors made of copper plate and wire. They were saddle shaped so as to go over the back of the Gymnotus or over the balls. They were open about 3 inches–about $3\frac{1}{2}$ high and $2\frac{1}{2}$ wide (along the lower edge). The wires brazed to them were about the $\frac{1}{10}$ of an inch thick and 8 feet long.

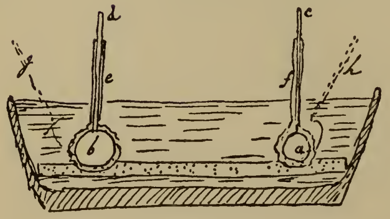


4996. These were as the hands, or as collectors of Electricity, from the gymnotus, and when used with the balls were put over them, the many folds of wet cloth being of course between them and the balls: and the wires were made to pass as in the figure, *g*, *h*, and not in between the two balls.

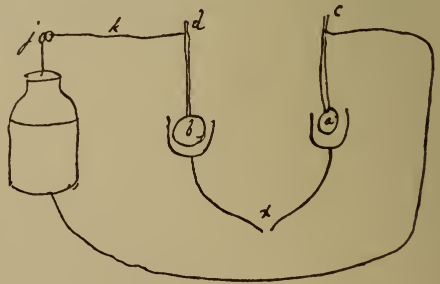
4997[†]. May now represent the whole arrangement thus. *c* was permanently connected with the outside of the Jar or battery, but *d* only occasionally connected when the discharge was wanted, and this connection, which may be called *k*, was sometimes metallic throughout and sometimes consisted in part of wet string. The effects were looked for at *x*.

4998. First a good sized jar fully charged was used, and when the communication *k* was metallic, a large bright spark could be obtained at *x*. Then also a shock could be obtained on applying the hands at *x*.

[*] [4994]



[†] [4997]



4999. But when 10 inches of thick double wet string made part of communication *k*, then *no* spark or shock could be obtained at *x*.

5000. In the latter case, the lowering of the intensity gave time for the water between *a* and *b* to carry all the electricity; none passed at *x*.

5001. Hence this jar does not hold electricity enough to at all equal that of the Gymnotus, for when it is so lowered in intensity as not to give a spark at *x*, which the Gymnotus electricity cannot, not under the same circumstances, do, then there is no shock by the collectors in the hand, which the gymnotus *can* do.

5002. I made myself part of the circuit at *k*, also including the wet string, so as to feel the reduced primary shock: the shock was rather strong.

5003. Using such thick and wet string, the spark at the Jar was flamy and dull, but still pretty sudden and the sound rather sharp.

5004. Now used the large Leyden battery of fifteen jars.

5005. A high charge, with the double string at *k*, gave no spark at *x* even when a very narrow interval in a strip of tin foil fixed on shell lac was used.

5006. Employed 6 folds of the same thick string well wetted, the hank being 8 inches only in length. I then obtained a feeble shock at *x*—but no sensible spark.

5007. Using the same charge and same six fold string at *k*, but putting the hands into the water near the balls *a* and *b*, I obtained a shock very much like that of the gymnotus shock at the Adelaide rooms.

5008. Assuming this to be the quantity and intensity therefore of a gymnotus shock, I again endeavd. to obtain a spark at *x* by a divided line of tin foil on shell lac, but could not, even when the fingers (dry), which held the wires of the collectors against the tin foil, felt the shock sensibly.

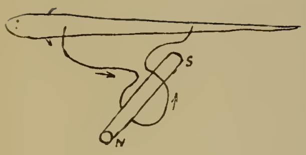
5009. Obtained polar decomposition of Iodide Potassium solution at *x* very easily, even when battery charged lowly only.

5010. Had made a helix on a quill, and using annealed needles, could easily render them magnetic at *x*.

5011. I think this arrangement is not far off a feeble or moderate gymnotus shock.

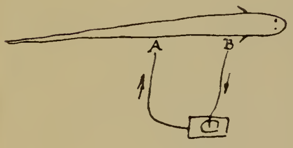
5012. Was at the Adelaide Gallery again; present Mr Bradley and Mr Gassiot. The fish had not had his water changed yet. Used the copper collectors, introduced at x my little helix containing $22\frac{1}{2}$ feet of wire (on a swan quill), and also one of Harris' thermo instruments, with the fine wire stretched across it, both being in the series at once.

5013. After touching the fish once or twice, could not tell by Harris instrument that any shock had passed, but examining the needle in the helix, *found it a magnet.* The arrangement was thus: the S end of the needle pointing to the S. and the N end to the north; consequently the current had been from anterior parts, through the wire to the posterior parts of the fish.

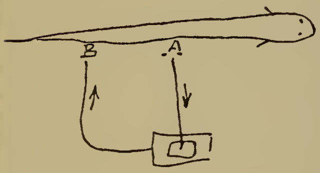


5014. Ascertained experimentally that the discharge of a Leyden jar sent in the same direction through the helix produced a magnet in the same direction.

5015. Now experimented with chemical action on iodide of Potassium at x, but calling one collector A and the other B. Then A was applied at the middle of the fish and B near the head or rather neck; the end of the wire attached to B evolved iodine, was positive and therefore the current was as marked by the arrows.

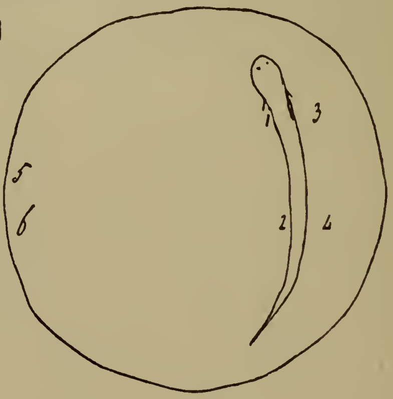


5016. Then applied B towards the tail, still keeping A at the middle, and now the wire of A was Pos., it having been negative before. So a part in the middle, which is negative to the parts before it, is positive to those behind it: or—anterior parts are positive to posterior parts, which are negative.



5017. Now endeavd. to ascertain whether three or four persons, each forming a separate circuit, could be shocked at once and without touching the fish; i.e. whether the discharge is in every direction through all the surrounding water or other conducting matter. To understand this must know that the tub, in which the fish is, is 46 inches in diameter, being circular, and the depth of water at the time $3\frac{1}{2}$ inches. The fish himself is 40 inches long to the tip of the tail. The general arrangement of things was as in the following diagram*.

* [5017]



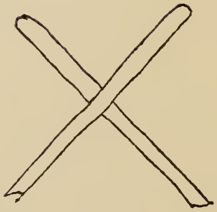
Mr Gassiot had his hands in the water at 5 and 6. I had mine in at 3 and 4, taking care not to touch the fish; and Mr Bradley had his hands at 1 and 2, it being his office to touch and provoke the fish to discharge. For the first few touches he would not satisfy us, but suddenly he gave a shock which startled us all and was perfectly satisfactory as to the generality of the discharge. Mr Gassiot evidently felt it least, and I dare say Mr Bradley most. That which I felt was as strong as any I had before received from the fish.

5018. It will be a good thing to keep the hands in the water, to know in experiments when the fish has given a discharge.

20 OCTR. 1838.

5019. At Mr Gassiot's, Clapham, to see the effect he has remarked of strikingly higher temperature at the Positive than at the Negative wire, when a good voltaic battery is discharged through Air. His battery was Daniell's, with brown paper instead of membrane, etc.,   pr. of plates. It gave a discharge through Air about ½ inch long. This Arc of discharge was beautifully affected by a magnet and in consequence of the related actions, *curiously extinguished* by it; i.e. when the arc was forced by magnetic action to go in the contrary way to the rising current of hot air, and so the discharge driven from hot particles of air on to cold ones instead of being *retained* on the hot ones. The cold air could not discharge through the $\frac{1}{16}$ of an inch, whilst the hot air could through half an inch.

5020. Besides the action of heat—does not the long arc of discharge shew the tendency of discharge to continue discharge, as stated generally in the xii and xiii series.



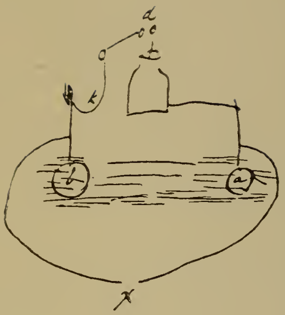
5021. Then for the particular phenomenon. Two thick copper wires, terminations of the battery, were crossed, and when discharge had occurred were separated a quarter of an inch or so, so as to continue the discharge between the two. Both wires heated, but the Positive far more than the other. It became red hot to the end, whilst the negative wire was black hot.

5022. When two thick platina wires were used, the effect was still better.

5023. There could be no doubt but that more heat was evolved between the air and positive wire than between the air and negative wire.

5024. The effect is, I believe, one of the many beautiful relations of Positive and Negative surfaces to the dielectric between them. It would be well to try the effect between platina wires in many gases and vapours; Oxygen and Nitrogen compared; also Vapour of Mercury.

22ND OCTR. 1838.



5025. Experimented this morng. with the apparatus (   ) in the ante lecture room and the large machine and Leyden battery, using the primary current, i.e. one taken directly from the wires of the balls and not from plates put near those balls in the water. The effect, as was expected, was nearly the same.

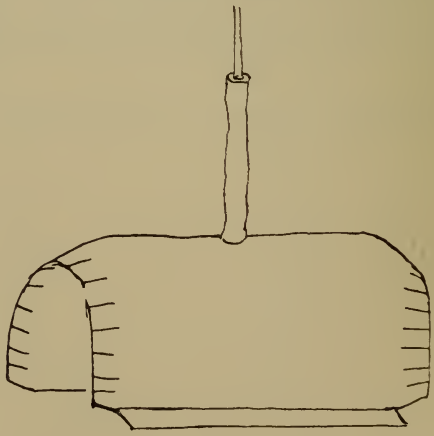
5026. Thus, when the string at *k* was eight folds of thick wet loose cord (the skein being about 12 inches long), the hands, put in the water near the balls *a* and *b*, felt a moderate Gymnotus shock, a full charge of the great Leyden battery being use[d]—and when the well wetted hands were applied to the wires at *x*, the effect was about the same.

5027. I could not obtain a spark at *x* over the smallest interval whilst both balls *a* and *b* were in the water. But when I took one out, I obtained a good spark at *x*, though a quiet one, analagous to that at *d* but not so large.

5028. In the Evng. at the Adelaide Gallery, to obtain further results, as the heating power, the spark, and certain effects dependant upon the current of Electricity around the fish.

5029*. The Saddle conductors (   ) I have fitted up with caoutchouc, covering them over on the outside by sheets of that substance kept in form by attached pieces of whalebone. The lower edges of these sheets extended outwards and the two curved edges were first made to converge and then split a little, so as to give way yet adapt themselves to the body of the fish. So when

* [5029]



plates of glass were put into the tub under the fish as a pavement; and when the Gymnotus was over them, these conductors were pressed down upon two different parts of his body. These parts were considerably insulated to what they would be if exposed in every direction to the discharging effect of the water.

5030. I also had two small collectors made thus[*]; A was a disc of copper 1½ inches in diameter, brazed by a copper rod *c* to a copper cylinder B. The part of the rod *c* at *d* was covered with caoutchouc, to insulate it. By grasping the handles B in a well wetted hand and applying the discs A to different parts of the body of the fish, the effect from those parts could be better distinguished than when the large surface of the hands was immersed. They acted very well.

5031. *Chemical action.* This was obtained abundantly on Iodide of Potassium as before. Collector at anterior part was positive.

5032. *Made Magnets.* We permanently magnetised several small needles in my helix. Daniell, Owen and others took specimens.

5033. We used Harris' thermo electrometer (the stretched wire) putting *at once* the Galvanometer, his instrument and the magnetizing helix into the circuit. By the same shock the fish deflected the galvanometer, raised the temperature in Harris' instrument and made a magnet.

5034. *Evolution of heat.* The rise of temperature was quite evident, but the amount of effect not much. The elevation was about half a degree on the instrument.

5035[†]. *Deflection of the Galvanometer.* The north end of needle went 40° to the East. The same direction of deflection was produced when the wire which was near the head was made to touch the copper, and that near the tail brought against the zinc of a single voltaic circuit. Hence the current was from the anterior through the instrument to the posterior parts of the fish, as before.

5036. The magnet made in the helix was found as represented, so that it also indicated, as before, and as always, the same direction of the current.

5037. *Spark.* Then tried for the spark thus. A good magneto electric coil, with a core of soft iron wire, had one extremity made fast to the end of one of my collectors (   ) and the

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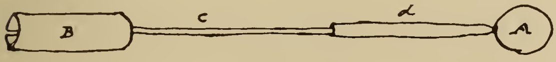
* [5030]



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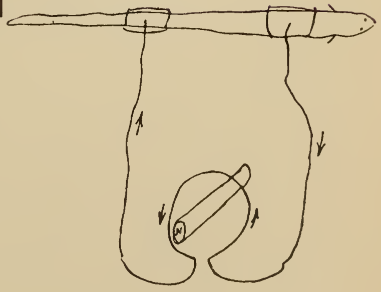


other fixed to a new steel file. Another file was made fast to the end of the other collector. One person rubbed the point of one of these files over the face of the other, whilst another person put the collectors over the fish and endeavoured to excite him to action. The object was, by making and breaking contact very frequently, to catch the moment of the current through the wire, and breaking it during the current, to make it sensible as a spark.

5038. The spark was obtained *four times*. Many saw it. I saw it only once, being engaged at the fish. We tried by friction alone of the files to produce the like effect, but did not, and considering all the circumstances, I am fully satisfied it was the Electric spark; thus obtained by these collectors whilst the fish was in the water.

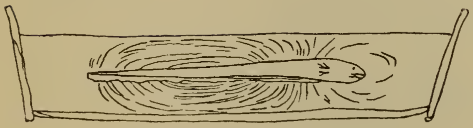
5039. Those who held the wires obtained shocks at these times. I felt them frequently. They were very small unless the hands were wet and in extensive contact with the wires. The effects are analagous to those of a voltaic battery, i.e. to Electricity of great quantity but low tension.

5040. Now with reference to the current in the water all round the fish. Every part of the water is for the moment filled with its influence and conducts, and the fish causes on all sides of him, above and below him, a current of Electricity from his anterior to his posterior parts. The lines in the diagram may generally represent this, but those which would accurately represent lines of equal force would doubtless differ somewhat in form from them.

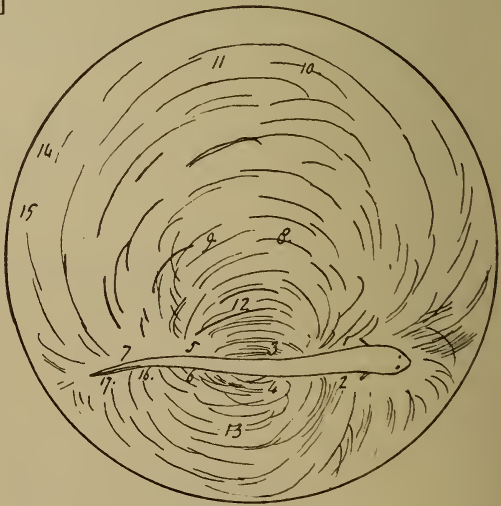
5041*. This may represent a vertical section of the fish in the water in a circular tub; and the following† may represent the horizontal section.

5042. When small collectors (   ) were applied at 1, 3, or 1, 4, or 3, 6, etc. etc., good shocks were obtained so as to shew their efficacy.

* [5041]



† [5041]



5043. When one person had the hands at 3, 5; another at 8, 9, and I applied and excited him at 1, 2, the first felt a strong shock, the second a weaker, but I felt scarcely anything.

5044. When I touched 3, 4, and another 3, 5, I felt scarcely anything; the other a strong shock.

5045. When one as A had hands at 12, 13, and B had hands at 8, 9, the latter felt a considerable shock and the former, by comparison, but little.

5046. When one took a strong shock at the first, another at 10, 11, and another at 14, 15, felt smaller ones.

5047. When one hand only was in, the shock was only in the part immersed.

5048. I excited him by touching at 16, 17, and felt a small shock, but another person at 8, 9, felt rather a *powerful one*.

5049. When touching with *both hands in* at 3, 4, or 5, 6, or 1, 2, I obtained merely a shock in the part of the hands immersed.

5050. When touching back and belly at the same section of the body of the animal (perpendicular to his axis), I had the effect only in the parts immersed—not in the arms or body.

5051. All these effects accord with the general view of the direction of the force already given. But what an enormous quantity of electricity there must be, to give such a general and universal shock.

5052. A live gudgeon was put into the water. Perhaps he was shocked now and then, but he was not killed and eaten. Indeed he must have had shocks frequently whilst we were at work.

5053. At last he took up his position, very frequently, with his nose close to and opposite the nose of the Gymnotus and remained there. Now this is a place of no discharge, and probably the fish found that out; but at the same time, it is the place of feeding for the Gymnotus if he had been hungry, and it would appear that this may be a natural provision to drive his prey towards his head and mouth.

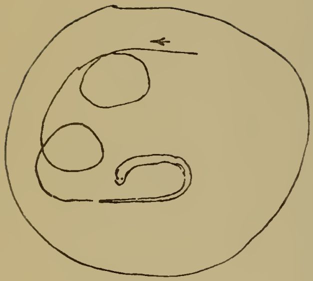
5054. There were present to-day Bradley, Gassiot, Owen, Daniell, Wheatstone, Dr. Todd, Young, Cowper, Anderson, Monyhan.

5055. Zinc and Platina plates were put into the water on each side of the head of the Gymnotus. He seemed to be more annoyed by them when connected than when not, but neither he nor the Gudgeon cared much for them.

5 NOVR. 1838.

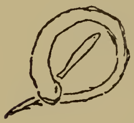
5056. At Adelaide Gallery to see Mr Bradley and fish. Understand from him that till my paper is given in to R.S., the fish is to be reserved to me. If it were not so, I could not think the paper worth receiving by the R.S. and would cancel it.

5057. The Gymnotus is in excellent health, very active and hungry. He follows the finger or any thing else put in the water.



5058. His mode of examining the water for prey is curious, and influenced, I have no doubt by his loss of one eye. The left eye is gone. As he moves on, after about a foot, he turns his head to the left and so makes a circle, after which he goes a little further and makes another. This was not always the case but very generally.

5059. On tapping the wood of the tub on the edge, the fish became quickly aware of it and active, and gave a shock, it being felt by Mr Bradley, who happened accidentally to have his hands in a considerable distance off at the other side of the tub.



5060. On putting a live fish in, about 6 inches long, the Gymnotus was instantly active and killed it at once in a remarkable manner. It was dropped in by the side of [his] neck. He instantly made a sort of coil or circle round, and there was the fish dead and stiff, with its side floating to the light. He had killed it in the instant. After this he turned about more leisurely, looking for it, and when he had found it took it[1] across in his mouth, but not being able thus to swallow it, he let it go, and then laid hold of it end ways and quickly bolted it. He still remained very active, searching for more food, so that another fish, much smaller, was given him, and this he swallowed apparently without shocking or killing it.

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[1] In the manuscript, folio volume III finishes at this point. The following words of par. 5060 are from the first page of folio volume IV.

FOLIO VOLUME IV
OF MANUSCRIPT

5 NOVR. 1838.

5061. It is very evident that when coiled round the fish the gymnotus shock will be most powerful on the fish enclosed.

5062. It is also very evident that, the larger the fish to be killed, the more powerful will be the shock it will receive, with the same exertion on the part of the gymnotus.

5063. Humboldt says the fish eats little and often. So that he probably has a quick digestion. It is said that things killed by Electricity quickly putrefy; nor is such an effect inconsistent with the sudden disturbance of the chemical affinities of the elements of the animal, considering it for the time as an electrolyte. Now there may be a direct relation between the digestive powers of the fish and the previous preparation of the food by the shock which it passes through it. Consider this and inquire further into the change of food by a strong discharge through it.

26 NOVEMBER 1838.

5064. Have made a little revolving file and fixed it on Daniell's whirling table; then using this and a Henry's coil, I succeeded this evng. in getting the spark from the Gymnotus again and again, sometimes between the revolving plate and a needle of steel and sometimes between it and copper; so that no mere attrition could have caused it. Also I had the shock, holding the wires at the moment the spark occurred.

5065. The spark was seen by Messrs Christie, Broderip, Roget, Gassiot, Bradley, Watkins, Clift, Anderson, Murray (at Newman's), Young, Cowper, Wheatstone and self.

5066. Tried Mr Wheatstone's apparatus. It did not do. It is beautiful in principle but requires more electricity.

5067. Tried for tension on gold leaves but could not.

3 DECR. 1838.

5068. At Adelaide gallery: Wheatstone, Talbot, Bradley, Watkins, Gassiot, Young, Cowper and self.

Wheatstone's apparatus did not do.

5069. Used Gold leaf Electrometer, 2 leaves: obtained no attraction of leaves, but a beautiful *direct* spark between the two balls above—the distance very small. The evng. was for Wheatstone's expts. principally.

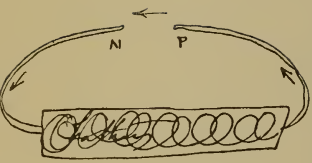
22 DECR. 1838.

5070. At Gallery again: Royle, Wheatstone, etc. etc. Had excellent spark with my revolving apparatus; sparks bright and 4 or 5 at once, i.e. in very quick succession. Good decomposition. Very powerful deflection and magnetization. Shock through 7 *persons* joining hands wetted. Could obtain no evidence of heating the wire.

5071. In the Afternoon previously I saw him strike and eat three fish. His mode of ingulphing them very curious: they seem to dart into his mouth, he so powerfully draws them in by the current of water which he forms.

1 MARCH 1839.

5072. Daniell has had a battery of, I think, 100 large cells at work and I was there. The following are certain results of transmission, heat, etc. etc. obtained with it, and very important on general principles. The terminations may be represented thus.



5073. First with the interrupted discharge, as in Gassiot's expt., the Pos. or P termination is far the *hottest*.

5074. When P is charcoal brought opposite to mercury as N, then there was a chattering sound and less volatilization of mercury. When P was the mercury and N the charcoal, there was a continual hiss and rapid abundant volatilization of the mercury.

5075. When P and N were both charcoal, then there is a transference of carbon from P to N, for P decreases and becomes hollowed whilst N increases and has tubercles formed on it which project into the cavity of P. That is, the hottest decreases, the coolest increases.

5076. When P was platinum (a fuzed globule) and N charcoal, then platinum travelled from P and was found on the surface of the N charcoal, encrusting it in covering drops: very beautiful. When P was charcoal and N a thick rod of platina, the latter was saved from melting and was covered with a thick coat of carbon which afterwards came off like a cap from the end of the platina rod.

5077*. All these effects seem to me to be simple consequences of the greater heat evolved at the P. surface compared to that at the N. surface. Thus, charcoal and platinum are volatilized in the course of the discharge and the space between is filled with their vapour. Now this will of necessity distil from the hotter to the cooler side and the transference is always in that direction. It is just like the water in the two bulbs of the cryophorus distilling from the hotter to the colder side. The phenomena with mercury is of the same character when the mercury is P.; it is much hotter and more is volatilized than when it is N.

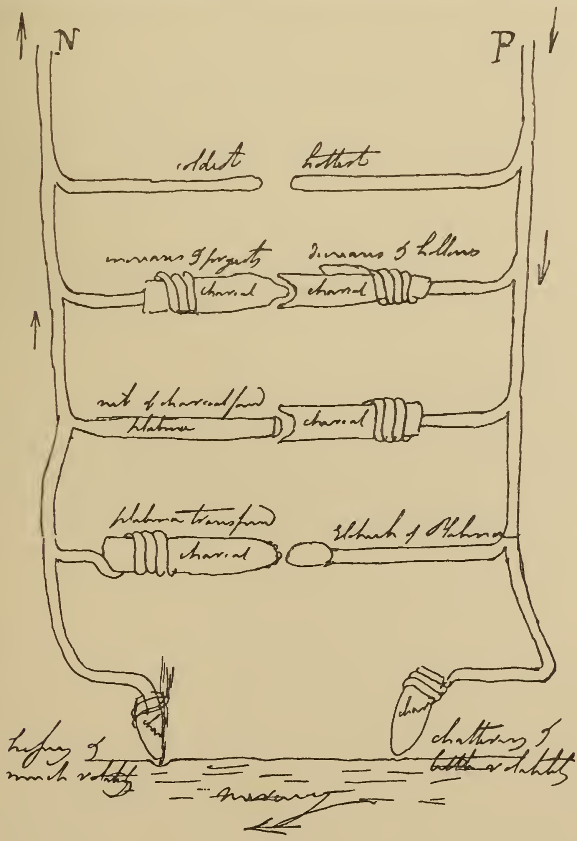
5078. I do not mean to say there is really no other reason for the transfer—but this one seems quite sufficient as respects these facts alone.

5079. Query the relation of the difference of the heat at the two surfaces to *thermo electric phenomena*: there must be a close relation some how or other. Make it out.

5080. This battery had no sensible striking distance, not even when the wires forming the interval were heated by a mouth blow pipe. I should like to try an oxy-hydrogen blow pipe heat.

5081. When according to Herschell's suggestion an electric spark was sent across the interval, it *did* determine the Voltaic discharge.

* [5077]



5082. I had an apparatus to shew Davy's elevations. They were not visible with large wires but came out with small ones. They were nothing like so powerful and striking as I expected.

5083. *Subject for investigation.* Whether vapours of metals do not *really* conduct and whether there are not differences as to conduction and insulation amongst vapours and gases, as there are amongst solids and liquids.

5084. Many experiments can be brought to bear upon this point —thus, discharge of voltaic battery across striking distance in vapours of Mercury, Zinc, Arsenic, etc. etc. etc. as compared to Air, sulphur, etc.

5085. Discharge between poles of Carbon and metals would agree with the supposition.

Must examine this point some day soon.

22 MAY 1839.

5086. The following references[1] are some left unused in the writing of Series XI, XII, XIII, XIV. I do not know that they are of further use, but because of my bad memory would rather keep them together here, least I may want them.

Is electricity on the electric or conductor? 2468–99, 2507, 16, 17, 19, 35, 95, 96, 97, 2648, 33, 50, 51, 52, 2706, 73, 78, 83, 84, 2860, 73, 74, 3591.

On exterior of conductors: 3508, 2709–12.

State of the interior of Do.: 2634–37, 49, 97, 98, 99, 2702–05, 36, 41, 46, 47, 49, 51, 52, 2816–20, 30–41, 70, 52–59.

Influence of form: 2470, 72–94, 2664–2705, 13, 14, 22, 37, 38, 39, 53, 54, 2813.

Large cube: 2808–25, 30–41, 43–59.

Points: 2470, 83, 85, 87–91, 98, 99, 2699–2701, 04, 15–24, 28–30, 38, 40, 2826, 27, 2854, 61, 63, 3244, 47–97, 3306–9, 52–63, 71–90, 3433, 35, 3583.

Drops: 2595, 3298–3305, 19–50, 91.

Action of lateral force here on point.

Motions of mercury in acids and solutions: 2533, 34, 3477.

Separation of plates under induction: Beccaria 3578, 2506–15, 51, 2864, 65, 74, 3427–30, 34, 67, 3502–06, 78, 4196, 97.

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[1] These references are to paragraphs of the Diary.

5087. Electrical axioms: 3772, 4, 5, 6, 7, 9, 3591, 4193.

5088. Electrical laws: 1904, 5, 6, 8, 9, 10, 11, 12, 4054.

5089. Relation of the Earth as an electrified globe to the space and planets around: 105, 414, 555.

2479, 2542–50, 2641, 2741–54, 2842, 4048, 52.

Remember the incoercibility of the power—we may be in very high electric relation to the sun and not know it: 2852.

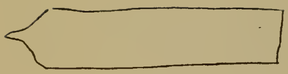
14 JUNE 1839.

5090. Examined the three charged tubes left on 24 Octr. 1837 (4179, etc.). All were still hermetically sealed and in that respect right; but on opening them, as was done with the former, not one of the three gave the least signs of charge. Hence I think clear result of conduction through the glass and consequent discharge.

24 AUGUST 1839.

5091. Expts. in reference to source of Electricity in V. Battery by contact or not.

5092*. Want an acid conductor sufficient for thermo currents or currents by contact of metals, and obtained one by the following arrangement. A glass vessel was filled with strong Nitric acid, and two platina plates with attached platina wires were put in also, not touching each other. These were about this size[1] and nearly half an inch apart. Then the circuit was completed by a galvanometer, copper wires and two bars of antimony and bismuth. The object was to ascertain if a thermo electric current, being one of the contact of two metals, could pass the acid in the glass.



5093. On putting the cold antimony and bismuth together there was no current shewn at the galvanometer; but on warming the ends of the anty. and bismuth and then closing the circuit, there was a powerful current shewn. Hence Nitric acid with these surfaces of contact with Platina *can conduct* such a thermo electric current.

5094. Instead of using the antimony and bismuth, a piece of platina wire completed the circuit from *p* to *a*. Whilst all was cold there was no current, but on heating *p* the galvanometer was deflected one way and on heating *a* it was deflected the other way.

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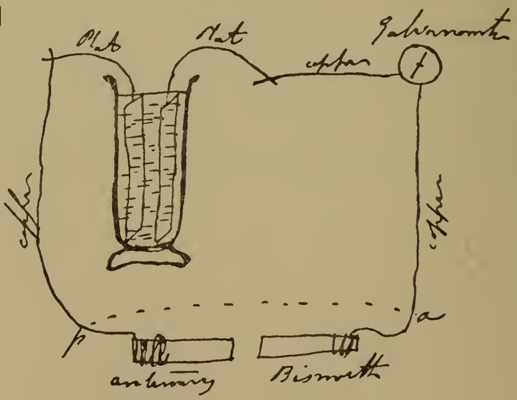
[1] The diagram is reduced to $\frac{1}{2}$ scale.

* [5092]



Hence the thermo-electric current of copper and platina thus excited is able to traverse Nitric acid.

5095. When dilute Sulphuric acid was in the glass between the platina surfaces, the copper-platina thermo electric current was scarcely sensible and the anty. and bismuth current very weak. When a mixture of 2 vols. Sulc. acid and 1 vol. of water was used as the conductor, the effect was much stronger. When a portion of Nitric Acid was added to the last it was greatly improved. Nitric acid seems very effective for these feeble currents.

5096. A solution of sulphate of copper with a little sulphuric acid added to it was used in the glass between the platina plates, and conducted the Anty.-Bismuth thermo-electric current very well.

5097. Solution of Nitrate of lead (ordinary)—did not.

5098. Solution of Nitrate of silver (ordinary)—did not.

5099. Thus there are several solutions across which the thermo electric currents of *metals in contact* can pass; i.e. if there be two opposing contacts as in*, a little excess of heat in one above the other will make a current that can pass. If therefore metals by contact tend to produce currents, surely an unopposed or single contact should produce a current capable of passing; or of two opposing contacts, as†, the stronger should give evidence of its formation by shewing a current determinated by it. So the Iron and platina being in N.A., contact 2 should shew its predominance over one. If a very little heat be added to either 1 or 2, its predominance is then immediately shewn.

26 AUG. 1839.

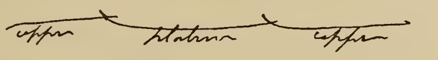
5100. Strong solution of *potassa fusa*, with platina plates in as before, did conduct thermo electric current of Anty. and Bismuth —but very feebly.

5101. Strong solution of *Sulphuret of potash* conducts thermo-electric current of *antimony and bismuth* very well; also that of *copper and platina*; also that of *Iron and platina*.

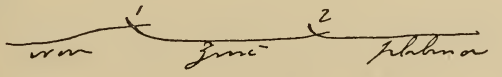
5102. *Mercury* in strong nitric acid yellow or colourless is dissolved.

5103. *Copper* in Do.—acted on—action strong at first, but soon stops because of formation of insoluble coat of nit. copper crystals. Galvanometer shews a continuous action.

* [5099]



† [5099]



5104. Silver in Nitric acid yellow or colourless acts also, but retarded by nitrate formed.

5105. Zinc acts very powerfully and at once.

5106. Lead acted on slowly.

5107. Tin—acted on very slowly, if at all. Must try it with the Galvanometer. Perhaps compare with Iron.

5108. Zinc is pos. to copper in sulphuret potash solution, as it is also in acid, and will not do for a battery without metallic contact. Iron is Neg. to copper in sulphuret potash, but Pos. to it in acid and will do.

5109. Silver is pos. to iron in sulphuret of potash or in sulphuret of lime solution.

5110. Sulphuret of lime solution acts with iron, zinc and copper just as sulphuret of potassa solution does.

5111. Consider whether contact produces a current or not.

5112. By the great argument that no power can ever be evolved without the consumption of an equal amount of the same or some other power, there is *no creation of power*; but contact would be such a creation. In all other cases of a constant evolution there is a constant consumption of something, as in

Chemical evolution
Thermo evolution
Magneto evolution
Animal evolution
Friction evolution.

5113. By the cases of copper, iron and sulphuretted solutions.

5114. By a battery of no metal contacts, in the order Zinc—acid—copper—Sulrt. Potash—Zinc, etc.

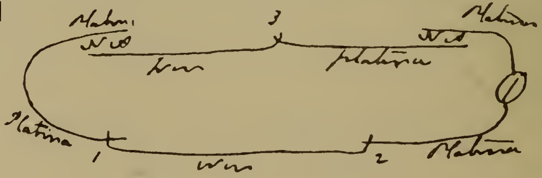
5115. By the necessary balance of opposed contacts so as to produce no effect of currents. It is so in the metals—it is so in other good conductors whenever their chemical action is stopped.

5116. By the absolute absence of a single case in which contact alone produces a current—chemical action is always present. Whenever in cases of a current the chemical action has been stopped, the current stops also, though contact continues.

5117. By the cases where chem. action without contact can produce a current.

5118*. By cases in which mere contact and thermo electric contact

* [5118]



are contrasted. Thus heat at 1 and 2 and compare effect with Non-effect at 3.

5119. Copper and Iron in sulrt. potash—copper was positive to the iron, i.e. as zinc to platina. It was left in the solution for 3 or 4 hours and still remained Pos. As the sulphuret of copper forms it swells up and separates in scales and the solution is continually having fresh access beneath.

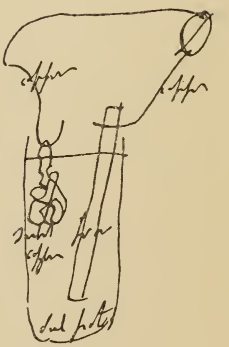
5120. Copper is also positive to Iron in common solution of caustic potassa—it rapidly tarnishes in it. I believe however that the caustic potassa had some oxide of lead in solution.

5121. When copper plates were left in sulphuret of potassa for 2 or 3 minutes—taken out—washed—dried—warmed and rubbed—the coat of sulphuret of copper appeared to be pretty compact and adherent. If left in longer, so as to form a thick coat, this would often blister up and separate even in the washing and drying; or especially if dipped into a fresh sulphuretted solution: the finger nail could remove large flakes of it. Hence this sulphuret of copper cannot be trusted in new expts. as preventing contact and action of the solution of potash sulphuret and the metal beneath.

5122. If a copper plate so covered with sulphuret be associated with an iron plate in solution of sulphuret of potash, at the first moment it is neg. and the Iron positive; but in period more or less long the copper becomes positive and the iron negative. Is the same in a solution of caustic potash.

5123. To explain this observe as follows:

5124. If copper wire be heated with abundance of sulphur it forms most excellent solid sulphuret in the form of the wire, and contact of the copper wire of the galvanometer with it is easily made. Such a circuit, i.e. sulrt. copper and Iron in sol. sulrt. potash, gives at first the Iron constantly pos. to the sulrt. copper, and not Neg. as Marianini supposes; and it is so also in solution of caustic potash.



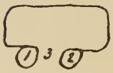
5125. But thinking this might be due to some temporary action on the sulphuret by the sulphuret of potash, I left them together for some time—then took out the sulrt. copper, washed it, dried it and again made the experiment. At first the iron was pos. to the sulphuret of copper, but in a few moments all action ceased and there was no current. Repeated this again and again with the same result.

5126. Thus though there was contact between the copper and the sulphuret and between the latter and the solution, yet there was no current, there being no chemical action. This was not from bad conducting power, for now heat applied at the junction of the Iron and copper wire immediately produced a thermo electric current.

5127. If either the sulphuret copper or the iron were taken out and held in the air for a moment, it on its reimmersion became neg. to the other which had remained in. If two platina plates were in sulrt. potassa, or a platina and an iron plate, and producing as usual no current, if either were taken out for a minute or less and re-immersed, it would be neg. to the one remaining in. If an active copper and iron plate were in sulrt. potash, the copper being positive, and it were taken out for a moment or two and replunged, it would for the first moment be negative, though it would soon become positive again. All these effects are consequent upon changes produced by the air upon the adhering sulphuret of potash, and are additional to the permanent effects belonging to the several cases (5177, 5325, 5961).

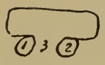
5128. So when a sulphuretted copper plate is associated with Iron in sulphuret of potash, it is first neg. and then positive: Neg. because it is in the condition of the plate exposed to the air and Pos. because, after a short time, the solution gets through the coat of sulphuret of copper and *chemical action* recommences. So contact itself and alone generates no current here.

5129. 1	2	3	
√Copper	Platina	A strong solution of pure caustic potassa	Copper Positive very slightly
√Copper	Iron		Do.
Tin	Platina		Tin very strongly Positive
Tin	Iron		Do.
Lead	Platina		Lead positively—moderate
Lead	Iron		Do.
Zinc	Platina		Zinc very positive
Zinc	Iron		Do.
Cadmium	Platina		Cadmium pos., about as lead
Cadmium	Iron		Do.
Antimony	Platina		Antimony pos. moderately
Antimony	Iron		Do.
Bismuth	Platina		Bismuth pos. moderate. Thermo current interferes
Bismuth	Iron		Do.
√Silver	Platina		No current after first moment
√Silver	Iron		Do.
Mercury	Platina		Mercury positive—fairly
Mercury	Iron		Do.
√Palladium	Platina		No current
√Palladium	Iron		Do.
Gold	Platina		No current
Gold	Iron		Do.
√Tin	Lead		Tin very positive
Tin	Copper		Tin very positive
Copper	Silver		Copper positive, moderate
Iron	Platina		No current
Nickel	Platina		Nickel pos. in least degree
Nickel	Iron		Do.
Palladium	Platina		Nearly alike. Perhaps Plat. pos.
Palladium	Iron		Do. Perhaps iron pos.
Rhodium	Platina		Plat. pos. very slightly
Rhodium	Iron		Iron pos. very slightly
Antimony	Bismuth		Ant. strongly pos.
√Cadmium	Zinc		Zinc is very strongly pos.
√Cadmium	Tin		Tin is very positive



5130. Copper and Platina in sol. ox. lead in potash—same as in pure potash.

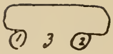
5131. Strong sol. of potash often not so exciting as a weaker, as with Antimony, Bismuth, etc. etc.



5132. 1	2	3	
√Copper	Platina	A strong solution of sulphuretted potash	Copper very pos.
√Copper	Iron		Do.
Tin	Platina		Tin moderately pos.—remains clean
Tin	Iron		Do.
Lead	Platina		Lead moderately Pos.—lead tarnishes slowly
Lead	Iron		Do.
Zinc	Platina		Zinc positive
Zinc	Iron		Do.
√Cadmium	Platina		Cadmium positive
√Cadmium	Iron		Do.
Antimony	Platina		Antimony pos.—does not discolour
Antimony	Iron		Do.
Bismuth	Platina		No sensible permanent current
Bismuth	Iron		Do.
√Silver	Platina		Silver strongly positive—discolours
√Silver	Iron		Do.
Mercury	Platina		Mercury strongly positive
Mercury	Iron		Do.
Gold	Platina		No sensible permanent current
Gold	Iron		
Arsenic	Platina		No sensible action
Rhodium	Platina		Plat. pos. at first—then became indifferent
Rhodium	Iron		Iron Do.
Iron	Platina		Nearly indifferent
Copper	Silver		Copper pos.—silver keeps clean whilst associated
√Tin	Copper		Nearly balanced; tin is pos.
Nickel	Platina		Nickel pos. in smallest degree
Nickel	Iron		Do.
Palladium	Platina		Alike nearly
Palladium	Iron		Pall. slightly positive—very little
Antimony	Bismuth		Anty. strongly pos.
√Cadmium	Zinc		Cadmium fairly positive
√Cadmium	Tin		Cadmium pos.—and continues so

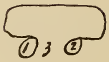
5133. Cadmium with plat. and Iron is at first pos. very strongly and then stops, as if when clean and the sulphuret was forming the current was powerful, but when formed insulated. Must see if the thermo-current is stopped at the same time—perhaps is only because formation of sulphuret ceases—will be a good expt. (5178).

5134.



1	2	3	
Silver	lead	A strong solution of pure caustic potassa	lead pos. fully
,,	tin		tin very pos. indeed
,,	cadmium		cadmium pos. and continues
,,	antimony		anty. pos.
,,	bismuth		bismuth pos.
,,	mercury		mercury pos.
,,	nickel		nickel a very little pos.
Copper	lead		lead very pos.
,,	tin		tin very pos.
,,	cadmium		cadmium very pos.—continues so
,,	antimony		anty. very pos.
,,	bismuth		bismuth moderately pos.
,,	mercury		mercury very pos.—good expt.
,,	nickel		copper pos. feebly
,,	silver		copper pos.
Palladium	lead		lead very pos.
,,	tin		tin powerfully pos.
,,	cadmium		cadmium Do.
,,	antimony		antimony pos. fairly
,,	bismuth		bismuth pos.
,,	copper		copper pos. moderate
,,	mercury		mercury pos.
,,	nickel		nickel a little pos.—then it went off
,,	silver		silver a little pos.—then went off
,,	gold		nearly alike
,,	rhodium		Palladium feebly pos.

5135.



1	2	3	
Silver	lead	A strong solution of sulphuret of potassa	silver pos. to lead
,,	tin		silver pos.—not strongly
√ ,,	cadmium		cadmium pos.—then ceases as before
,,	antimony		silver pos.
,,	bismuth		silver pos. very strong
,,	mercury		silver pos. strong
,,	nickel		silver pos. very strong
Copper	lead		copper pos. if plate—neg. if a wire
,,	tin		copper fairly pos. either plate or wire
√ ,,	cadmium		cadmium pos. at first—then ceased
,,	antimony		copper plate very pos.
,,	bismuth		copper plate very pos.
,,	mercury		copper plate pos.

	1	2	3
	Copper	nickel	copper plate very pos.
	"	silver	copper still pos.—silver free from tarnish
	Palladium	lead	lead pos.
	"	tin	tin pos.
√	"	cadmium	cadmium pos.
	"	antimony	antimony pos.
	"	bismuth	bismuth pos. slightly
	"	copper	copper very pos.
	"	mercury	mercury pos.
	"	nickel	nickel *neg.* very slightly
	"	silver	silver very pos.
	"	gold	alike
	"	rhodium	rhodium *neg.* very slightly

5136. Copper not regular—had copper plate and copper wire—the first very strongly pos. to the second—copper plate often Pos. to silver but silver always pos. to the copper wire—difference of copper very striking.

5137. *Copper and silver*—copper was pos. and silver kept clean—then in a few seconds silver became pos. and began to tarnish—then again the copper became pos. and so on—a good illustration of chem. action and dependance of current on it.

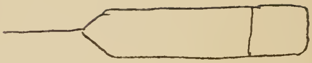
AUG. 31, 1839.

5138. The following bodies were tried as to evident conducting power of a thermo current from a single contact of *Antimony and bismuth*, a galvanometer being in the circuit and the contact made merely by pressing the bodies between connecting copper wires.

Conductors	*Non-Conductors*
Galena	Hæmatite
Yellow sulphuret of Iron	Native per oxide of tin
Arsenical pyrites	Wolfram
Native sulrt. copper and Iron	Native Mag. oxide of Iron
Artificial sulrt. bismuth	Elba iron ore
Artificial sulrt. iron	Artificial sulrt. tin, grey
Artificial sulrt. copper	Fuzed protoxide of copper
Globules of Oxide of burnt iron	Blende
Iron scale by heat	Per oxide of mercury
Native per ox. Manganese feebly	Cinnaber

Conductors	*Non-Conductors*
Artificial Sulrt. silver—when pretty hot conducted feebly this current	Per oxide of copper Nit. lead crystals
Black sulrt. mercury—? the mercury in it which is loose.	

The following are fluids or melted bodies, contact with them being by platina plates of about this size[1], and about half an inch being in the fluid.



Chloride of silver—the solid chloride does not	Melted nitre ,, nit. soda
Fluoride lead—Do.	,, chlorate potassa
	,, sul. soda—in its water of crys.
	,, chloride lead—red hot

The solutions do not conduct the thermo current, i.e. not sensibly with this arrangement.

5139. The *Fluoride of lead*, when melting conducted, but it gave so strong a changing current as to overpower and even hide the effect of the thermo current. The contact with the fluoride was by two platina plates, and by putting these into different situations in the fluoride, so as to make one hotter than the other, the hot platina was pos. to the colder platina, as if a thermo current was there produced and indicated.

5140. But I am not quite sure the platina were exactly alike, and judging from the sudden way in which the current jumped about and changed in direction very suddenly and powerfully, I suspect that sometimes one plate was acted on and sometimes the other. If this be so, it will with the same contacts give beautiful proof of the dependance of the current on chemical action; and I must use pure substances and try to work out such cases.

5141. With *chloride of silver* something of the same kind occurred. Pursue this enquiry in connection with the illustrations derivable from inversions of the current.

SEPT. 10, 1839.

5142. Fuzed *Nit. silver*: same thing—current first one way, then the other, and changing continually. Easy reduction of silver may perhaps assist this varying action—or if have occasion to repeat must have very clean Nitrate and vessels and a flame or heat not acting on the salt at the required temperature.

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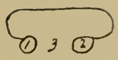
[1] The diagram is reduced to $\frac{3}{4}$ scale.

5143. Experimented with solutions. The following conduct the thermo current of 1 Pr. Anty. and bismuth very well (5138).

Sol. Sulrt. Potassa	freely
Sol. Sulrt. lime (by boiling) . .	as well as N. Acid
Strong N. Acid	very well indeed
1 vol. N. A., 4 vols. water . . .	very little—just sensible
Sol. Sul. copper with some S. Acid	moderately.

5144. The following solutions may be considered (for my purpose) as non conductors of the same current. Some conducted a little, and I dare say the current could be made sensible in all, but it was not enough to class them with the former bodies.

Strong Sulphuric acid
Do. with half its bulk of water
Do. 10 volumes of water
The last with a little nitric acid
Muriatic acid strong and pure
Sulpho cyanic acid—weak solution
Potassa caustic—strong solution
Lime water
Chloride of lime—Bleaching liquid
Chloride—Carb. soda—Labarraque
Chloride lead—saturated solution
,, calcium—strong solution
Chlorate potassa—saturated solution
Nitrate Potassa Do.
Nitrate Soda Do.
Sulphate Soda Do.
Nitrate lime—strong solution
(5097) Nitrate of lead
(5098) Nitrate of Silver



5145.

1	2	3	
Platina	Sulrt. copper artificial	Sol. potash	little at first—no continuing action
Iron	,,	,,	Iron a little positive
Silver	,,	,,	Silver very little negative
Copper	,	,,	Copper *powerfully* positive?

1	2	3	
Platina	Sulrt. copper artificial	Solution of Sulphuret Potash	Platina very positive indeed!
Iron	,,		Iron a little negative?
Silver	,,		Silver very positive
Copper	,,		Copper very positive
Platina	Sulphuret of copper and iron native	Sol. of Sulphuret of Potash	Platina very positive!
Iron			Iron a little positive
Copper			Copper very positive

5146. Precautions, etc. A piece of sulphuret of copper, native or artificial, which has been into a solution of sulphuret of potash and out again, and having been washed and wiped, is used again in a few minutes with a fresh unused piece, is always strongly positive to the latter. Anything dipped in the sulphuret and exposed to the air acquires positive powers by such treatment.

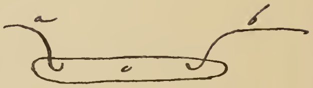
5147. Above. Platina and Sulrt. copper in sulrt. potash gave platina very positive indeed occasionally—in fact often; but sometimes it was not so, and a piece of sulrt. copper left in sol. sulrt. potash for 18 hours, and then two plat. plates connected with the galvanometer being put into the solution, when either one was made to touch the sulrt. copper the other was Neg.; so that in this case the sulrt. copper was a little positive to the Platina.

5148. Have made some fresh Sulphuret of copper by heat, etc., to examine this action more closely.

5149. Platina and native sulrt. copper and Iron form a very sensitive thermo-electric couple. So also Platina and native sulphuret of Iron.

5150. *Thermo-electricity.*

If *a* and *b* be copper wires connected with a galvanometer and *c* a plate of platina, whilst all are at the same temperature nothing happens; but on rubbing *a* on *c* the heat produces a good thermo electric current. As the heat is *all* at the place of contact, this would be a good mode of comparing the quantity of heat and Electricity equivalent to each other. Thus *a* and *c* with friction ought to heat a certain amount in a certain time with a certain friction if the circuit were not complete, but if the circuit were complete then they should heat more slowly.



5151*. Again, if circuit were not complete, rubbing *a* on its platina

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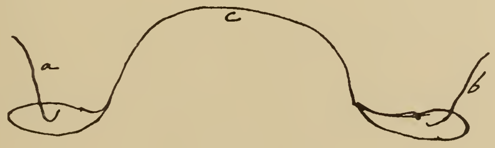
* [5151]



surface should produce heat there, but no change at *b*, etc.; but if circuit complete, should produce less heat at *a* and develope a quantity at *b* equal to the diminution at *a*, etc. etc.

5152. The sulphuret of copper, made of thick copper wire from 0·2 of inch thick downwards, appears to be very good and perfect and forms fine cylindrical pieces. Each piece of wire appears to enlarge much during the production of the sulphuret.

5153. Made a first rough experiment with it:

	1	2	3	
1	Platina.	Artl. Sulrt. copper	Sol. Potash	Platina fairly Negative
2	"	Native Sulrt. copper and Iron	"	Platina evidently Pos.
3	"	Artl. Sulrt. copper	Sulrt. Pot. Sol.	Platina much more Neg. than 1
4	"	Native Sulrt. copper, etc.	"	Platina highly Positive

5154. Hence the Native and Artificial sulphurets are here in contrast. One reason why sol. caustic potash does not act so powerfully as the sol. of the sulphuret is that it is a much worse conductor of the current produced.

5155. I put some pieces of the Artificial sulphuret of copper into the sol. of Sulphuret of Potash, that any further sulphuration or action might go on to a terminal or quiescent state. In at 2 o'clk. P.M.

5156. The per sulphuret probably would lose sulphur in the solution of potash or even of sulphuret of potash.

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5157. The Sulphuret of copper in sol. sulrt. potash of yesterday had acted much. I had put a piece of platina in also to form a continual voltaic circuit and this platina was encrusted pretty thickly with sulphuret of copper. I think that the Artificial sulphuret has gone on taking sulphur from the solution and throwing down copper on the platina, which has become sulphuretted by being in the solution. If so, then the sulphuret will ultimately acquire a final state higher as to sulphuration than that left by heat. The effect proves also that copper as a sulphuret is held *in solution.*

5158. This sulphuret, whilst still in the solution, was conjoined with Platina and still found to be fairly positive, as if the combination of sulphur with it was still going on. It was therefore left in the solution with a plate of platina also in it and in contact.

5159. This sulphuret, conjoined with dry Artificial sulphuret of copper in the sulphuret of potash solution—first one and then the other was pos., changing about, as if like action was going on at both, but opposed and varying in amount.

5160.

1	2	3	
Platina	Artl. Sulrt. Copper	Solution of yellow Sulrt. Potash	Platina fairly Negative
Iron	,,		Iron Do.
Silver	,,		Silver fairly Positive
Copper	,,		Copper full Positive
Platina	Native Sulrt. Copper and Iron		Platina very Positive
Iron	,,		Iron Do.
Silver	,,		Silver Do. indeed
Copper	,,		Copper Do. ,,
Artl. Sulrt. Copper	,,		Artl. Sulrt. Copper very Positive

5161. Now to compare with solution of caustic potash, on the supposition that the force depends in the cases of the per sulphuret of copper and iron to the *giving up* of sulphur, as contrasted with the force and its direction when the copper *takes* sulphur.

1	2	3	
Platina	Artl. Sulrt. Copper	Solution of caustic potassa	Platina little Neg.
Iron	,,		Iron very little Neg.
Silver	,,		Silver Do.
Copper	,,		Copper fairly Pos.
Platina	Native Sulrt. copper & Iron		Platina little Pos.
*Iron	,,		Iron first Pos., then indifferent
*Silver	,,		Silver Do. Do.
Copper	,,		Copper slightly permanently Pos.
Artl. Sulrt. Copper	,,		Artl. Sulrt. Copper very pos.
Copper	Silver		Copper is fairly Positive

5162. In all the expts. of this page, new pieces of artificial sulphuret of copper were used for each fresh expt., but with the Native sulphuret the same piece was used, the end, after being dipped in the solution, being taken out, washed in water, wiped with a cloth and then used again. Now this produces for the first moment a Neg. state in the sulphuret, after its use in Caustic potash, as was found by direct experiment, probably from the dilute film at first on its surface. This must be considered in the experiments marked thus *.

5163. Copper is Pos. to silver—by direct action in Caustic potash.

5164. The difference between sol. sulrt. potash and sol. caustic potash is very great, especially when considered as abstractors of sulphur from the per sulphuret. It is probable that potash can not do this, but that *Sulrt. potas*SIUM can, and hence the difference; Potash not being the fit electrolyte—the consistent one—or the affinity of its potassium for sulphur not being strong enough. Must try there the solution of proto sulphuret of potassium as an abstractor from Per sulphuret, and also its relation to the Artificial sulphuret of copper.

5165. Will a hot solution of potash abstract sulphur from the per sulpherets, as of copper, Iron, etc. etc.?

5166. It is very striking to see that when Native Sulrt. copper and Iron with solution of caustic potash is associated with first copper and then Artificial sulrt. copper, the latter is far more positive than the former, though when they are opposed to each other in the same solution of caustic potash, the copper is positive to the Sulphuret. I must verify and examine this. This probably depends upon the relation of sulphur to the connecting electrolyte; but is it not at all events against the theory of contact?

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5167. The Sulphuret of copper left in on the 11th (5158), being examined, had caused no deposition on the connected platina, so that its action is falling much. Being associated with Platina and also Iron in solution of sulphuret of potash, it was still Positive to the platina and iron, but its action much weaker than before. It was put into a fresh solution of sulphuret of potash and left to go on and come to a fixed point.

5169[1].

1	2	3		
Platina	Artificial Sulrt. Iron		Platina fully Neg.	After the first moment of immersion of the sulphuret of iron it was evidently acted upon and action increased
Iron	"		Iron Do.	
Silver	"		Silver Do.	
Copper	"		Copper Strong Neg.	
Platina	Native Yellow Sulrt. Iron	Solution of pure Caustic Potassa	Platina the least degree Neg.	
Iron	"		Iron Do.	
Silver	"		Silver a little Neg.	
Copper	"		Copper fairly Positive	
Artl. Sulrt. Iron	"		Art. Sulrt. Iron Very Positive	
Platina	Galena		Neutral	
Iron	"		Iron a little positive	
Silver	"		Silver Do.	
Copper	"		Copper fully Positive	
Lead	"		Lead fairly Positive	
Silver	Sulrt. Silver		Nothing: sulphuret not conduct	
Tin	Sulrt. Tin artificial		Tin very Pos.	
Tin	Artl. sulrt. Copper		Tin very Pos.	
Platina	Artl. sulrt. Tin Grey		Sulrt. Tin Pos.—it rapidly colours the sol. Potash	

5170. The pieces of sulphuret were all clean and good. When a piece was used, as the crystal of Iron pyrites, it was not taken out of the solution for each metal, but left in, one part being above the surface and quite clean and dry; and then when the metal at the other side was immersed, this part was used for contact to complete the circuit.

5171.

1	2	3
Platina	Artificial sulrt. Iron	Platina Pos. a very little
Iron	"	Iron, indifferent
Silver	"	Silver, very Pos.
Copper	"	Copper, very Pos. indeed

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[1] 5168 is omitted in the MS.

1	2	3	
Platina	Native Yellow Sulrt. Iron	Solution of Yellow Sulphuret of Potassa	Platina the least Pos.
Iron	"		Iron indifferent
Silver	"		Silver very Pos.
Copper	"		Copper very Pos. indeed
Artl. Sulrt. Iron	"		Artl. Sulrt. Iron a little Neg.
Platina	Galena		Platina distinctly Pos.
Iron	"		Iron a little Neg.—then ceased
Silver	"		Silver Pos. strongly
Copper	"		Copper very Pos.
Lead	"		Lead Pos. a little
Silver	Sulrt. Silver		Nothing—sulrt. silver not conductor
Tin	Artl. Sulrt. Tin		Tin little pos. for a moment
Tin	Artl. Sulrt. Copper		Tin a little Neg.

5172. The pieces of sulphuret were used here with the same precautions as in the experiments with sol. Caustic potash.

5173. *Artificial Sulphuret of Iron.* Made some, but cannot form it in the same fine cylinders as the sulphuret of copper. It is too fusible and runs down into a mass.

5174. *Sulphuret of Cadmium.* Made some directly from the metal and sulphur. It requires a high heat for combination and then much heat is evolved. The resulting sulphuret does not fuze at good high temperature; when cold is of a fine yellow colour. It appears to be a non-conductor of the thermo current of Antimony and bismuth.

5175. Platina and Cadmium in sol. yellow sulphuret of Potash. Cadmium was first strongly positive and then the action diminished; but it did not stop entirely as before.

5176. *Proto sulphuret of Potassium.* Passed sulphuretted hydrogen through a solution of caustic potassa. After a while used a little of this as a trial with true hydro sulrt. potassa. The following are some preliminary results:

1	2	3	
Platina	Silver	the solution	Silver fully Pos. and tarnishes
"	Copper		Copper fully Pos. and tarnishes
"	Copper Pyrites		Copper pyrites strongly Negative

So here solution gives sulphur to copper, but takes it from per sulphuret of copper. The pyrites quickly changed colour in the solution and became black; but we must try all this again. Action of this solution very different to that of potash.

5177. Much care is required as to exposure of the immersed substances into THIS hydro sulrt. of potash as well as the other. If two pieces of platina be used, they are at first seldom alike, but become so if left quiescent. Then if they be alternately raised and depressed in the solution, that which has been exposed to the air for a moment is always Positive to the other, and much so at the first moment; though the effect (if all is quiescent) soon becomes neutral. This is, as far as it goes, against contact and for chemical action (See 5325) (5127, 5961).

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5178. Examined the action of Platina and Cadmium in a strong and a weak solution of yellow sulphuret of potassa in reference to the complete suspension of all action on the part of the Cadmium after the first moments (5133, 5135, 5175). Whether the solution were strong or weak the action falls, and at last is very little. If the metallic surface is polished by knife cleaning, the action is less and sooner falls than if it is roughened by sand paper cleaning; as was to be expected.

5179. Bodies producing non conducting insoluble results cannot be supposed to give activity by these results acting by contact.

5180.	Platina	Iron	Solution of colourless hydro-sulphuret of potash	Platina a little Pos.—then ceases
	”	Lead		Lead Pos. moderately
	”	Silver		Silver very Pos.—tarnishes moderately
	”	Copper		Copper very Pos.—tarnishes rapidly
	”	Zinc		Zinc Pos. well
	”	Cadmium		Cadmium Pos. well
	”	Tin		Tin very Pos.
	Iron	Lead		Lead Pos.
	”	Silver		Silver very Pos.
	”	Copper		Copper very Pos.
	”	Zinc		Zinc Pos. moderately, then quickly fell to little
	”	Cadmium		Cadmium Pos.—then falls, but not quite
	”	Tin		Tin very Pos.

Lead	Silver	[Solution of colourless hydro-sulphuret of potash]	Silver Pos. strongly—and tarnishes
”	Copper		Copper very Pos.
”	Zinc		Zinc is Pos.
”	Cadmium		Cadmium strongly Pos.
”	Tin		Tin very Pos.
Silver	Copper		Copper very Pos.—silver remains bright
”	Zinc		Zinc Pos. at first—then balanced
”	Cadmium		Cadmium Pos.
”	Tin		Tin very Pos.
Copper	Zinc		Zinc slight Pos.—copper tarnishes
”	Cadmium		Cadmium Pos. at first—then very little or neutral
”	Tin		Tin very Pos.
Zinc	Cadmium		Cadmium a little Pos.
”	Tin		Tin a little Pos.
Cadmium	Tin		Cadmium a little Pos.

5181. The hydro sulphuret of Potassa was made by passing sulphuretted hydrogen through a solution of pure caustic potassa. It gave much sul. hydrogen by action of an acid and appeared to be very good; but there may have been excess of potash, though the gas was passed through for 24 hours.

5182. The order of the metals appears to be

5183.

1	2	3 with *colourless hydrosulphuret of potash.*	
Platina Iron Silver Copper	Native grey Sulphuret of Copper	Platina strongly Neg. Iron Do. Silver Strongly Pos. Copper Do.	The sulphuret was acted upon, changed colour, became blacker: and probably combined with sulphur
Platina Iron Silver Copper	Native compact yellow copper pyrites	Platina a little Negative Iron distinctly negative Silver strongly Positive Copper Do.	
Platina Iron Silver Copper	Artificial grey Sulphuret of Copper	Platina Negative Iron Do. Silver Positive Copper very Pos.	
Platina Iron Silver Copper	Artificial Sulphuret of Iron	Platina strongly Pos.—goes down afterwards Iron scarcely Pos. Silver very Pos. Copper most Pos.	

Platina	a cubic crystal of native Yellow Iron pyrites	Platina indifferent—little Neg.
Iron		Iron a little Neg.
Silver		Silver Pos.
Copper		Copper full Pos.

Platina	Galena	Platina negative
Iron		Iron negative
Silver		Silver very Pos.
Copper		Copper very Pos.

5184. The piece of sulphuret, when once put into the solution, was left there until the four metals were compared with it—so change by exposure to air was avoided.

5185. The exciting solution was the *colourless hydro sulphuret of potash* described in the last page.

5186.

1	2		3	
Platina	Native grey Sulphuret of Copper		Platina a little Pos.	
Iron			Iron Do.	
Silver			Silver Neutral	
Copper			Copper very Pos.	
Platina	Native compact yellow copper pyrites	Solution of pure caustic potassa	Platina very little Pos.	
Iron			Iron rather Pos.	
Nickel			Nickel fairly Pos.	
Silver			Silver very little Pos.	
Copper			Copper very Pos.	
Platina	Oxide of Iron, being globules of burnt iron		Platina indifferent	This oxide of Iron is as Platinum: nearly
Iron			Iron least degree Pos.	
Silver			Silver Neg. faintly	
Copper			Copper Pos. fully	
Tin			Tin very Pos. indeed	
Art. Sulrt. Copper			Art. Sulrt. Copper Pos.	
Platina	Native crystd. per oxide of Manganese		Platinum well Pos.	There is an undoubted direct action of the per oxide of manganese in originating a current. What is it?
Iron			Iron Do.	
Nickel			Nickel Do.	
Rhodium			Rhodium Do.	
Palladium			Palladium Do.	
Gold			Gold Do.	
Silver			Silver Do.	
Copper			Copper very Pos.	

5187. That oxide of Iron, being a conductor, should be the same as Platina and also the *same as Iron* in both solution of caustic potash and sulphuret of potash, must be against the theory of contact. Will it be so in Nitric acid also?

5188. Must make out the per oxide of manganese action; probably there is separation of oxygen from it in both cases, i.e. both here and in next page[1].

5189.

1	2		3	
Platina	Native Grey Sulrt. of Copper		Platina little Neg. See (5345): mistake here.	
Iron			Iron—neutral	
Silver			Silver—Very Pos.	
Copper			Copper—Very Pos.	
Platina	Native compact yellow copper pyrites	Solution of yellow sulphuret of potash	Platina—little Neg.	
Iron			Iron very little Pos.	
Nickel			Nickel fairly Pos.	
Silver			Silver very Pos.	
Copper			Copper Do.	
Platina	Oxide of Iron, being Globules of burnt iron		Platina little Pos.	The Oxide of Iron is as Platinum here.
Iron			Iron indifferent	
Silver			Silver Pos.	
Copper			Copper Very Pos.	
Tin			Tin. Do.	
Art. Sulrt. Copper			Art. Sulrt. Copper Pos.	
Platina	Native crystd. per oxide of Manganese		Platina powerfully Pos.	There is quick action on the Per oxide of Manganese. It becomes grey and much lighter in colour: is most likely deoxidized.
Iron			Iron Do.	
Nickel			Nickel Do.	
Rhodium			Rhodium Do.	
Palladium			Palladium Do.	
Gold			Gold Do.	
Silver			Silver Do.	
Copper			Copper Do. most	

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5190. Examined again the action of the native yellow sulphuret of copper, which on some occasions has seemed highly Negative to Platina and Iron when in solution of sulphuret of Potassa; using first the compact yellow copper pyrites lately bought at Mawes and then the former old fissured piece from the museum.

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[1] i.e. in par. 5186 and in par. 5189.

The latter is evidently irregular and probably a part of the iron present may have become oxidized.

5191. First with solution of *colourless hydro sulphuret of potassa* as 3.

Platina	Compact yellow copper pyrites	The pyrites was in the least degree Pos.; very nearly neutral	
Iron	Do.	The pyrites a little more Pos. than as above	
Platina	Old copper pyrites	Variable—pyrites a little Pos.	Part of this sulphuret blackened in the solution, and it gave something to the solution, making it yellow
Iron	Do.	The pyrites a little pos. to the Iron	

5192. Now the same substances were used in a solution of *the yellow sulphuret of potassa.*

Platina	Compact pyrites	Neutral, again and again.
Iron	Do.	Pyrites very little Pos.
Platina	Old Copper Pyrites	Platina very Pos.!
Iron	Do.	Iron very Pos.!

The pyrites in these [last] two experiments was certainly very negative; the pyrites was fissured and pervious. I must make out how pyrites becomes negative. Perhaps if it were pulverised it would do something by allowing plenty of contact.

5193. It seems at all events that when there is no chemical change that there is no current. Mere contact is not enough.

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5194. Per oxide of manganese, native, which has been left in solution of caustic potassa for several days, has rendered it yellow, as if chrome had been there and dissolved. The per oxide is still a little Negative to Platina, but not as it was before.

5195. Artificial Sulphuret of tin left for some days in solution of caustic potassa. The sulphuret has become loose and inadhesive, i.e. it has lost much of its cohesive force. In a fresh solution of potash it again causes discoloration and further action and it is Positive to Platina. It is also still positive in the old potash solution. Chemical action is still going on there.

5196. Have been ascertaining the general order of metals, etc. in seven solutions which are given in the next pages[1]. Those beneath are Positive to those above: the test was a galvanometer. No attempt was made to estimate the degrees of Pos. and Neg., or rather to express them, but the differences of the metals are far greater in the lower part than above. In many cases the 5 or 6 bodies at the top of the columns were nearly alike; they were as like to each other as two pieces of platina would be to each other or two pieces of any other single metal. The slightest accidental circumstances caused differences here, and it is not so much the first impression as the permanent current that is of importance and ought to decide. At the same time, the first impression is very important in many cases, as in Iron for instance, etc.; also in those cases, as with cadmium, silver, etc. etc., where the investing body formed at the first moment reduces and almost stops the after action; or as with silver, copper, etc., changes its direction altogether. Those bracketed in pencil were apparently quite alike.

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[1] i.e. par. 5197.

5197. ORDER OF BODIES (BY GALVANOMETER) IN SEVEN SOLUTIONS[1]

	Strong Nitric acid		1 acid, 7 vols. water Dilute Nitric acid	Strong Muriatic Acid	Dilute Sulc. Acid	Sol. caustic potassa	Sol. colourless Hy. Sul. Pot.	Sol. yellow sulrt. Potash	Substances to be introduced
1	Plumbago	2	Platina	Plumbago	Palladium	Rhodium	Iron	Rhodium	Plumbago Scale Oxide of Iron Native Iron pyrites „ Copper „ „ Grey Sulph. Copper „ Per. ox. Manganese Galena Per oxide lead Artifl. Sulrt. copper „ Sulrt. iron „ Sulrt. bismuth
2	Platina	3	Gold	Rhodium	Platina	Plumbago	Platina	Plumbago	
3	Gold	1	Plumbago	Palladium	Gold	Mercury	Palladium	Iron	
4	Rhodium	4	Rhodium	Platina	Plumbago	Platina	Nickel	Nickel	
5	Palladium	5	Palladium	Gold	Artfl. Sulrt. copper	Gold	Gold	Palladium	
6	Iron, peculiar		Mercury	Sulrt. Copper Artl.	Silver	Palladium	Rhodium	Platina	
7	Nickel	9	Silver	Antimony	Rhodium	Silver	Bismuth	Gold	
8	Artifl. Sulrt. Copper	8	Artl. Sulrt. Copper	Silver	Copper	Artl. Sulrt. Copper	Lead	Bismuth	
9	Silver	11	Copper	Nickel	Antimony	Nickel	Silver	Lead	
10	Antimony	10	Antimony	Bismuth	Bismuth	Copper	Antimony	Artl. Sulrt. Copper	
11	Copper	13	Bismuth	Copper	Nickel	Iron	Mercury	Mercury	
12	Iron, ordinary	7	Nickel	Iron	Iron	Bismuth	Copper	Tin	
13	Bismuth	12	Iron	Tin	Tin	Lead	Tin	Antimony	
14	Tin	14	Tin	Lead	Lead	Antimony	Cadmium	Copper	
15	Lead	15	Lead	Cadmium	Cadmium	Cadmium	Zinc	Silver	
16	Zinc	17	Cadmium	Zinc	Zinc	Tin		Zinc	
17	Cadmium	16	Zinc	*Mercury?*		Zinc		Cadmium	
				Plumbago gave a yellow colour to the Mur. acid and was clearly Neg. to Rhodium, etc. etc.	*Mercury?*		*Art. Sul. Copper* *Plumbago*	Plumbago and platina a very good distinct circle here	

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[1] In the manuscript, the words printed in italics, the numerals to cols. 1 and 2 and the brackets in this table are in pencil.

5198. Lead and Tin in Muriatic acid. Lead is decidedly pos. at first and then tin becomes so and continues. This I believe is because lead has the highest action, but the chloride formed then invests it and prevents chemical action going on there; but at the tin it does go on, and so that in turn becomes positive, the tin chloride being far more soluble than the lead chloride.

5199. The electro contact of the chloride of lead can do nothing as to causing a counter current at the lead, for it is a non conductor and its immediate action is therefore limited.

5200. Again, Lead and Iron in Dilute Sulc. Acid. The lead is first very Positive to the Iron, but in a few moments the Iron becomes Pos. to the lead and continues so, and for a similar reason to that above. Again, Lead and Tin in the same dilute acid produce similar effects, but not so strong. Probably the same thing would happen with several of the metals above these.

5201. Copper and silver in yellow sulphuret of potash. Copper is Pos. first, being strongest, but as soon as sulrt. copper is formed, then the silver becomes Pos., and then another change comes on again, beautifully varying. As above, how can this be contact when carefully examined?

5202. The same thing happens with two pieces of silver or of copper, and the changes are very beautiful. How can this be contact?

5203. Zinc with copper in yellow sulrt. potash is first positive, then loses its power.

5204. Two pieces of silver in Muriatic acid change very frequently in their relation and very beautifully: how is this contact?

5205. Could pick out many other cases of changes with 2 pieces of one metal, and also of falls of power as body produced accumulates.

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5206. Made various arrangements with the bodies which can conduct thermo currents to see if it were possible to find one which, without chemical action and by contact alone, could affect the galvanometer, i.e. act. The following are such arrangements:

Platina	Iron	Plumbago
"	"	Scale Oxide Iron
"	"	Native Grey Sulrt. Copper
"	"	" Copper pyrites
"	"	" Iron pyrites
"	"	" Per ox. manganese
"	"	" Galena
"	"	Artl. Sulrt. Copper
"	"	" Sulrt. Iron
"	"	" Sulrt. Bismuth
Platina	Zinc	Plumbago
"	"	Scale Oxide Iron
"	"	Native Grey Sulrt. Copper
"	"	" Copper Pyrites
"	"	" Iron Pyrites
"	"	" Per oxide Manganese
"	"	" Galena
"	"	Artl. Sulrt. Copper
"	"	" Sulrt. Iron
"	"	" Sulrt Bismuth
Platina	Plumbago	Scale Oxide of Iron
"	"	Native Grey Sulrt. Copper
"	"	" Copper pyrites
"	"	" Iron pyrites
"	"	" Per ox. Manganese
"	"	" Galena
"	"	Artl. Sulrt. copper
"	"	" Sulrt. Iron
"	"	" Sulrt. Bismuth
Zinc	Scale Ox. Iron	Native Grey Sulrt. Copper
"	"	" Copper Pyrites
"	"	" Iron pyrites
"	"	" per ox. manganese
"	"	" Galena
"	"	Artl. Sulrt. Copper
"	"	" Sulrt. Iron
"	"	" Sulrt. Bismuth
Copper	Plumbago	Scale oxide of Iron
"	"	Native Grey Sulrt. Copper
"	"	" Copper pyrites
"	"	" Iron pyrites
"	"	" Per ox. manganese
"	"	" Galena
"	"	Artl. Sulrt. Copper
"	"	" Sulrt. Iron
"	"	" Sulrt. Bismuth
Copper	Scale ox. Iron	Native Grey Sulrt. Copper
"	"	" Copper pyrites
"	"	" Iron pyrites
"	"	" Ox. Manganese
"	"	" Galena
"	"	Artl. Sulrt. Copper
Copper	Scale ox. Iron	Artl. Sulrt. Iron
"	"	" Sulrt. Bismuth
Copper	Grey Sulrt. Copper	Native copper pyrites
"	"	" iron pyrites
"	"	" per ox. manganese
"	"	" Galena
"	"	Artl. Sulrt. Copper
"	"	" Sulrt. Iron
"	"	" Sulrt. Bismuth
Copper	Copper pyrites	Iron pyrites
"	"	Per oxide Manganese
"	"	Galena
"	"	Artl. Sulrt. Copper
"	"	" Iron
"	"	" Bismuth
Copper	Iron pyrites	Per oxide Manganese
"	"	Galena
"	"	Artl. Sulrt. copper
"	"	" Iron
"	"	" Bismuth
Copper	Per ox. Manganese	Galena
"	"	Artl. Sulrt. Copper
"	"	" Iron
"	"	" bismuth
Copper	Galena	Artl. Sulrt. copper
"	"	" Iron
"	"	" bismuth
Copper	Art. Sulrt. Copper	Artl. Sulrt. Iron
"	"	" bismuth
Copper	Art. Sulrt. Iron	Art. Sulrt. bismuth
Platina	Copper	Artl. Sulrt. Copper
Copper	Platina	Iron pyrites
Iron	Platina	Iron pyrites
Copper	Plumbago	Iron pyrites
Iron	Plumbago	Iron pyrites
Platina	Plumbago	Iron pyrites
Copper	Iron	Iron pyrites

Again, Copper, Platina, zinc and plumbago with Iron pyrites, thus:

Copper	Platina	Iron pyrites
Zinc	"	"
Copper	Plumbago	"
Zinc	"	"
Platina	"	"
Copper	Zinc	"

5207. Great care was taken to exclude thermo currents, and then in none of these cases was any current produced. If change of temperature to a degree so small that the junctions did not differ by more than a degree was allowed, then a current was manifest by the Galvanometer, shewing the readiness with which any current could be allowed and detected in the system.

5208. It cannot fairly be objected that these are conductors and so the current generated is lost, because conduction in thermo arrangements is advantageous and ought to be so here; nor is it assumed to be an objection in the case of the junction of the different metals of the voltaic series.

5209. If it is said an electrolyte is required, that is begging the whole question. First, there is more resistance by far in electrolytes. To neutralize this objection and obtain a probable current, it must be assumed that the action of the electrolyte is unlike that of all the conductors, and that when a zinc and platina pair are connected by one, the opposite tendencies in the circuit are not balanced. But this is simply an assumption; no experiment shews it, for whenever the current is produced there is always chemical action to produce it.

5210. Look at the cases of two pieces of the same metal in the same acting fluid, as copper or silver in Sulrt. potash or in muriatic acid, or fifty other, and compare them with two pieces of platina or iron in the same fluids; and look at the case of Iron and platina in Nitric acid, at common and higher temperatures, etc.

5211. All the cases of inversions, etc. amongst similarly acting bodies are virtually referred by the contact men to chemical conditions. Thus the changes of copper and Iron, etc. in acid and in sulphuret. The inversions of the metals A and B in two different acids, etc. are in every case made to bend to the chemical action.

5212. Copper alone in sulphuret potash forms a sulphuret of copper—here is an active force which can become a current. It is not that the current must first be formed and then the sulphuret be produced. On the other hand, when sulphuret ceases to be formed then the current stops, though all the bodies concerned are conductors and contact still is there.

5213. In cases of inaction, i.e. want of current, we must make a grand distinction between those where the current cannot pass, as when copper is Pos. in Sulpho-nitric acid, and those where it is free to pass, even when so feeble as a thermo current, as with Iron in Nitric acid.

5214. I put 5 bottles away, numbered, and with substances in them to take their final state for the purpose of testing if they were motors by contact or by chemical action.

No. 1. Plumbago in dilute N. Acid, 1 Acid, 5 Water. (5859).
No. 2. „ „ Strong solution of Muriatic acid. (5855).
No. 3. „ „ solution of caustic potassa. (5861).
No. 4. „ „ solution Yellow sulphuret potassa. (5865).
No. 5. Native per ox. manganese in solution of caustic potassa.

These were all closed up carefully and put away in a dark place.

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5215. In order to consider and also to state the question of exciting contact, we may represent things thus*, where *a*, *b* and *c* a[re] points of contact between platina and zinc, zinc and acid, acid and platina: the arrows represent the direction of the supposed excited current and the numbers are assumed as representing the force of their production.

5216. Now if platina zinc contact is equal to a force of 20 →, then zinc platina contact will be admitted to be equal to ← 20, or else a current would occur in such a circle, i.e. one of platina and zinc only.

5217. It is not likely that when the acid is introduced, as in the diagram, its contact with platina should be the same as zinc contact with platina, and yet that its contact with zinc should be equal to 5 →.

5218. Nor is it likely that the acid contact with platina should introduce a less additional ← power than the → power it causes at the zinc, so that whatever variation it may make, the powers should still be balanced.

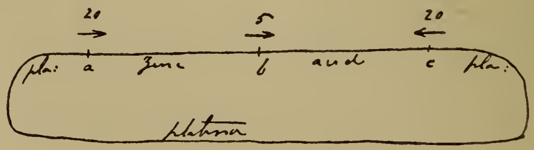
5219. Still, if it is to be assumed that the class of such bodies as electrolytes would exhibit differences able to give a balance of power in one direction (it being provable that the class of conductors *will not do so*), then we might at all events expect that alkalies would give the contrary current to acids; but the fact is that it gives the same, for Potash in place of acid gives still the same current and in the same direction.

5220. Also some acids give a difference, i.e. an inversion, when an alkali may be selected that will not.

5221. There is in fact no general ruling influence of acids or alkalies apart from their *pure chemical relations*. The theory makes them bend about to suit the real results, and these bendings are exactly what the chemical forces indicate; to my mind they shew the true relation and subjection of the bendings to the chemical forces.

5222. Thus the contact theory is obliged every where to mould itself on the chemical theory, and after all can shew *no case* of *pure*

* [5215]



electro contact current. There are abundant cases of pure *electro chemical* currents.

5223. The sulphuretted solutions illustrate well the windings of the contact theory, against all reasonable analogy, that it may by running parallel to chemical action be in any way consistent with the facts.

5224. The cases of iron and nitric acid are explained by pure assumptions by the contact men, but are simple results of previous chemical facts.

5225*. Every case of a current is obliged to be met by the contact men by assuming powers at the points of contact of strengths sufficient to produce it. So the metals *a*, *b* with acid at *c* give → current, but with acid there give ← current; also with alkali at *c* give → current and with sulphuretted alkali give ← current. Is this likely from contact action alone?

5226. Again, the fluids and , which give different currents with *a* and *b*, will give the *same* currents with the metals *e* and *f*; whilst the fluids giving the same currents with *a* and *b* give different currents with *e* and *f*.

5227. If we say that the effects of contact always balance each other in a complete circle, then where is the source of power? The power itself is in such cases a perfectly gratuitous assumption.

5228. If they do not always balance each other, then where is the case of a circuit producing a current by contact, chemical action being no way concerned?

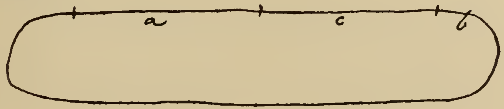
5229. If the many cases without chemical action produce no current, and those only with chemical action produce a current, then why should we not say that it is the chemical action produces it?

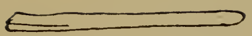
5230. Especially as there are so many cases of currents from chemical action *without* previous contact.

5231. If the contact theory is true, then may the perpetual motion also be true on principle, and it would not be difficult even to make one acting mechanically.

5232. *Gymnotus*. I saw the fish at the Adelaide Gallery not only give a spark across a striking distance, and attract gold leaves together hanging near to each other, but burn or deflagrate the leaves [in] a very striking and effectual manner. The leaves were

* [5225]





each about this size, and full one half of each was dissipated. This was some months ago.

5233. A voltaic battery giving no striking distance of itself would perhaps do so if connected with a good large Leyden battery. It ought if it can charge such a battery so as to give a sensible spark.

5234. *Induction.* Professor Henry's secondary, tertiary, etc. currents are not currents in the ordinary sense of the word, i.e. are not like a battery current continued for a moment. They are commencing or terminal currents, i.e. are beginnings or endings of a tonic state, are risings or fallings of a *condition.* Hence a very important difference. See 6088 to 6187 for working out of this matter.

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5235. I want such bodies as, being conductors of a thermo-current, are not acted on sensibly or at all by strong nitric acid. Some Nitric acid was boiled to drive off nitrous acid, cooled and then tried with different thermo-conductors.

Artificial Sulphuret of copper
Native sulphuret of copper and Iron
√ Nickel
√ Antimony
Bismuth
Arsenic
√ Native Sulphuret of Iron
Galena
Copper
√ Grey native Sulrt. copper

All acted upon at once and continued to be acted upon, some more, some less. Copper and its compounds become encrusted with scales of nitrate of copper, and action seems to stop, but in reality still goes on, more slowly. The four marked thus √ are acted on but slowly.

5236. A piece of grain tin in the N. acid did not appear to be acted upon but remained bright. When clean platina terminations (of the galvanometer) were put into the acid, and one made to touch the tin, no current was produced; the Tin did not appear to be positive to the platina. If whilst things remained thus the surface of the tin were scratched with a glass rod or with the other plate, then the tin became Pos. for a moment, but fell again instantly, as if the surface were quickly invested with a coat of oxide.

5237. The experiment shews very well the renewal and stoppage of the current with the renewal and stoppage of chemical action.

5238. A Piece of tin cleaned by scraping or sand paper does not shew the same perfect stoppage of chemical action. The action is at first strong and sudden, then quickly falls very much, but still goes on, and the consequence is, a permanent current is produced when it is opposed to Platina. It is only the tin pieces that have been separated by heat that occasionally produce this perfect stoppage; and that a coat of oxide covers them and protects them is sufficiently shewn by their yellow colour.

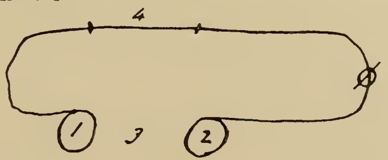
5239. I tried with a piece of such tin, part being in and part out of the acid for the connection, to see if a thermo current could pass the coat of oxide; but there was always a weak hydro current enough to overpower the thermo current, produced probably at the surface of the acid, where the moisture of the air may cause an action on the tin.

Platina	These did not appear to have any sensible action on the nitric acid.
Gold	
Plumbago	
Per oxide Manganese	
Scale oxide of Iron	
Iron	

5240*. Now for applications of these. Suppose 1 and 2 two such dissimilar metals as Platina and Iron, whilst 3 is such a fluid as strong Nitric acid or sulphuret of potassa, producing no current with the metals, but a conductor of a thermo current. Let 4 be a thermo electric arrangement and let a galvanometer be in the circuit. When all is cold or at the same temperature there will be no current, but on heating the thermo arrangement there will be a current. Then might get good proof that contact of metals is not effective in the voltaic pile by comparing the non-action of *contact* of Iron and platina at 4 with the action of a feeble thermo current there.

5241. Made 1 Platina, 2 Iron, 3 Strong N. Acid and 4 an Antimony bismuth thermo arrangement (a single element). In this case there was a permanent current, the Iron being positive, so that I could

* [5240]



not commence from the Zero state of things. On heating the thermo-element, which was fitted to produce a current in the contrary direction, it produced no sensible change in the deviation of the needle.

5242. I used a larger platina plate opposed to the iron plate; the effect was the same.

5243. I changed the iron plate for an iron wire only; the permanent deflexion was much less, but still the thermo current was not sensible by any alteration in the deviation.

5244. This nullity of effect may occur in two ways: either the nitric acid may not conduct the thermo current well enough, or the thermo current passing may so far be supposed to undo the peculiar state of the iron as to develope in it an equal amount of Pos. force, which producing its amount of current, neutralizes the effect and so keeps the deflection constant.

5245. I therefore made both electrodes in the N. Acid Platina and then heated the thermo electric element as before, but I obtained no sensible effect, though when the electrodes were made to touch each other in the acid there was very powerful effect. In fact then, this Nitric acid does not conduct the thermo current well enough for this kind of experiment; and has the further disadvantage of causing a rather strong direct current with the Platina and Iron. Perhaps a yellow acid conducts thermo current better than a colourless one.

5246. On taking away the thermo electric element at 4 and putting a little dilute Sul. Acid, for the purpose of having a comparative result, at *the same spot* of *contact*, of *thermo action* and of *chemical action*: then found the last to be striking, a strong electric current dependant on the dilute S. A., Platina and Iron being produced and continuing permanently. This is a good case of a voltaic action without contact.

5247. Supposing we had had no current from the Iron and Platina in N. A., then the *non effect* of contact of Iron and Platina at 4 would have been evident. In that case other metals, as zinc, put at 4 between the iron and platina there, would have shewed whether they had any effect; for it could not be supposed that the contact of zinc with platina and zinc with Iron would be alike in any other case than the one of *no action*. As it was I introduced

Zinc
Gold
Silver
Copper

and no change was produced in the deflection. Scale oxide of iron caused a slight diminution of the deflection, but this I concluded was not because it produced a counter current but because, being a worse conductor than a metal, it retarded the existing current. Had Iron and platina in N. A. produced no action, these two cases would have been separated and the true nature of the action of the oxide of iron shewn by itself.

5248*. I now made the fluid at 3 a strong solution of yellow sulphuret of potassa, leaving 1 and 2 Platina and Iron. At first the Platina was Positive to the Iron, as in former cases, but gradually this effect decreased and the Iron became Pos. to the platina, producing at last a permanent considerable deflection. The greatness of this deflection does not depend so much on the greater action on the Iron as on the far better conducting power of this solution, as was evident by the thermo effects to be described.

5249. On taking the iron out, cleaning it with sand paper and reintroducing it, the same series of effects was observed—the Iron was first negative, then positive.

5250. On heating the thermo electric app. at 4, its influence was very evident and good; but it was not strong enough to counteract all the Pos. effect of the Iron and bring the needle to zero.

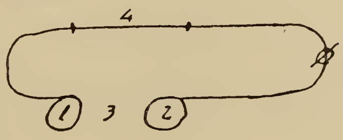
5251. When a little Sulc. Acid, diluted, was put between the Iron and platina at 4, it exhibited powerful effects, for the direction of the current was now inverted; the current was also very strong on the Galvanometer and hydrogen was evolved on the platina wire opposite the iron in the acid, none being evolved on the iron itself.

5252. This shews that the Solution is better than nitric acid; that a good electric current was produced without metallic contact and that weak chemical action at 4 is very far stronger than metallic contact at 4, if that be any thing at all.

5253. The introduction of Zinc
Gold
Silver
Copper

at 4 made no change in the effects.

* [5248]



5254. To sustain the theory of effective contact at 4, it may be said that sulphuret of potash acts by contact, as a metal would do there, and so there is a balance of forces; but then how is it shewn that it is not so in every case and with all fluids? If it be so with sulrt. potash, it is so also with the contrasted body, Strong N. Acid; and if with strong N.A., why are we to suppose that weak N.A. would have any other effect by contact only. Yet weak N.A. put at 4 and acting chemically has altogether a different result.

5255*. 1, 2 and 3 were Platina, Iron and sulphuret of potassa. Copper, platina and a galvanometer were in the circuit elsewhere, as marked, being merely wires twisted together at the junctions. There was a little permanent deflection, the Iron being Positive. When heat was applied at either *a* or *b*, the thermo effect was fully evident at the Galvanometer. Heat at junction *a* made iron 2 more pos.; heat at junction *b* made iron 2 less positive. The thermo effect was not so much as the chemical effect of the Iron (5264).

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5256. *Per oxide of lead*, which has been boiled in several distilled waters until all the Nitric acid and nitrate of lead have been removed, then dried in warm air cupboard, is an excellent conductor of thermo electric currents. Very surprizing to find such substances as the Per oxide of lead
Per oxide of manganese
good conductors; their protoxides not being so. These bodies most likely conduct as metals and not as electrolytes.

5257. Compared colourless and red nitric acid as to conducting power for a thermo current. Some Nitric acid, strong, was boiled and cooled and put into a circuit by means of platina plates, the circuit including a galvanometer and a thermo electric couple of Antimony and bismuth. When all was quiet the thermo-pile was heated, but the nitric acid conducted scarcely at all; the effect was not sensible.

5258. Some very red Nitric acid, i.e. with much nitrous acid in it, was then put in the place of the colourless nitric acid. This conducted the thermo current very freely indeed. Its effect is quite

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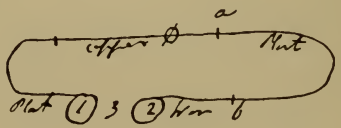
* [5255]



remarkable and I should think a thermo current would pass half a dozen or more interpositions of it.

5259. Either platina plate dipped in colourless nitric acid and then replaced was strongly negative to the other. Either being raised into the air for a moment and then replaced was also strongly negative. This last result is due to the dissipation more or less of the Ns. acid by exposure to the air, the plate becoming as if dipped in nitric acid.

5260. Nitric acid which had been diluted with its bulk or more of water and then rendered green by the action of a platina cathode upon it (in Mr Grove's battery), was tried and found to be an excellent conductor of the thermo current, though it must have been comparatively weak as a nitric acid.

5261. If either plate was here raised into the air for a moment or two it became negative (on reimmersion) to the other, as in the former case.

5262. I used the red acid (5258) to make a circuit with Iron and platina (in 5241), including a galvanometer and the Antimony bismuth thermo element. There was a permanent deflection, the Iron being pos. as with nitric acid. But the thermo current could *now pass* and undo or counteract a part, perhaps one half, of the whole amount of deflection. This confirms the opinion given before (5244).

5263*. The cups D and E contained a strong solution of a newly prepared sulphuret of potassium with as much sulphur as possible. Cup D contained besides a plate of platina, continued by platina wire to the junction *a*; from thence iron was continued (as iron wire) to junction *b*; from thence platina to a galvanometer and again platina from the galvanometer to the plate of platina in the cup E. Then another platina plate and wire from that cup to junction *c*, and from there iron to the iron plate in the cup D, completing the circuit. In this circuit, three metallic junctions occur between Iron and platina: two at *a* and *b* which are contrasted or opposed to each other in direction, and one at *c*, which is not opposed by any other metallic junction.

5264. I found that this arrangement gave no current, i.e. that the Iron and platina in the cup D did not generate a current. It is true

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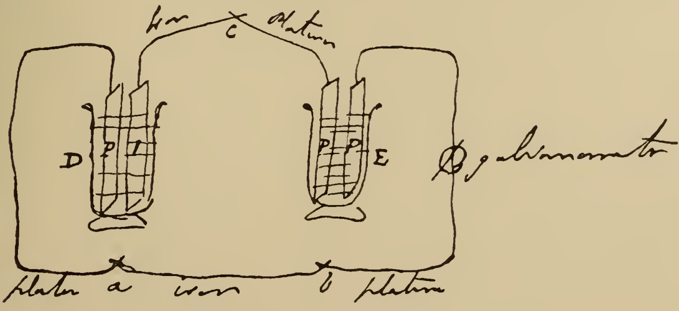
* [5263]



that at the first immersion the platina was Pos. to the Iron, as in the former case, but this gradually went down, and after an hour there was no sensible current, and at the end of five hours it was the same. The iron did not become positive as before (5255).

5265. Still I found that the circuit was of high conductibility, for heat at *a* instantly caused a current one way and heat at *b* as readily caused one the other way, the permanent deflection being easily rendered 60°, 70° or 80°. When *a* was heated, the current was from the Iron to the platina in Glass D and when *b* was heated, from Platina to the Iron. When neither was heated there was no current.

5266. Now why was there no current? Why did not the contact at *c* cause a current, if contact can do any thing? The mere warmth of the hand there caused a current, and if the Iron and platina were separated there and a little dilute acid or even the tongue or a wet finger applied there, such change caused a current. Why then did not contact, if contact can do any thing? The only answer the contact men can give is to say that the sulphuret of potash solution acts by contact as a metal and so the influences at the opposite surfaces are balanced.

5267. But this is altogether begging the question. The solution is certainly a most excellent exciting electrolyte when such metals or bodies are in it as it can act upon, as for instance copper or silver or probably per oxide of lead; and is then in its action quite unlike the metals and quite like any of the acid or saline exciting electrolytes. And if it, acting purely by contact, has its contact effects at the opposite surfaces balanced, then why should not all other exciting electrolytes have the same balanced action as regards their mere contact? And in either case it would not be contact but chemical action, and chemical action only, which produces the voltaic current.

5268. *Yellow sulphuret of Potassa* used above. Took equal weights of potassa fuza and sulphur (rather more sulphur), heated them together in a florence flask, first moderately and then more highly, until sulphur began to sublime, shaking the materials together for half an hour. Allowed all to cool. This sulphuret, dissolved in water so as to make a strong solution (from which the sulphur in excess fell by standing), gave the solution used in the preceeding experiment. It conducts most readily even a slight thermo current and it does not produce an active circuit with Platina and Iron.

5269. When the Iron and platina are first put into this solution the Iron is strongly Neg. to the Platina. I think this is because a little film or trace of oxide on the iron is being reduced by the solution. For the iron to attract oxygen is to make it the Positive metal; for it to give up oxygen is to render it a negative metal.

5270. I introduced Zinc
Gold
Silver and even Potassium into the circuit at *c*, but none produced any effect when the metallic contact was complete. Yet it is clear their contact effects on the Iron and platina could not be alike.

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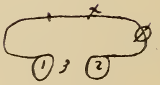
5271. Recommenced experiments with the good solution of sulphuret of potassium (5268) and metals which, being associated in it as a circuit, either produce no direct current; or produce a current at first and then come to rest, leaving a conducting circuit; produce a current and then come to rest producing a non-conducting circuit; or produce a continuous and permanent current.

5272. When 1, 2 and 3 were *Iron*, *Platina* and the solution of *Sulphuret of Potash*, it has been found already that they come to a quiescent or zero state, no current being produced (5264), and yet the system a good conductor.



5273. Made 1 and 2 *Platina and bismuth.* The bismuth was first positive; the current then gradually fell until very little. The current was shewn by a galvanometer included in the circuit, and a thermo-electric element of antimony and bismuth was also in the circuit, so arranged that when heat was applied, the current was as if 2 or the Bismuth were more Positive. On heating this element, it was found that the current freely travelled through the circuit, so it is still a good conductor. Continued this thermo current a while to assist in sulphuretting the bismuth and bringing it to its quiescent state. Let all cool to one temperature, and found that deflection of the Galvanometer needle by the remaining action of the bismuth was only 3° in this very delicate instrument. Yet on heating, the thermo element could pass its current and make it 40° or more.

5274. Cannot doubt therefore here that, as the action on the bismuth ceases, the current ceases also; yet the contact of the bismuth and platina remained unchanged and the current was not stopped for want of conducting power.

5275. When the point of contact of bismuth and platina had a little force given it by action of heat, that it continued to shew as long as the heat continued.

5276. Here we may reason, as before with the Iron and Platina (5266, 5270), about contact of Bismuth and Platina. It does nothing—and this case is not one of peculiarity, as with the Iron and platina, where the platina was *Pos.* at the commencement; but here it is negative, the bismuth being Pos. whilst the action goes on of sulphuration, and as that diminishes and ceases the current also diminishes, and at last (no doubt) also ceases, though all still a conductor.

5277. It cannot be that contact of the sulphuret of bismuth formed with the bismuth (see Marianini's notion in the case of copper) causes the first action and the current; for, independent of the loose state of such a case, that contact still continues, the sulphuret being insoluble, and yet there is no continuous current—it ceases with the action.

5278. Besides reasoning here on the inefficacy of the contact of bismuth and Platina, may extend it as before to interposed bodies, as zinc which was interposed there; copper also and all the other conductors would doubtless do the same thing, i.e. do nothing.

5279. The inactive bismuth, when taken out and washed, was found covered at the immersed part with an adhering thin brown film of sulphuret, like a very thin varnish or lacquer. It is in a beautiful state as an investing body.

5280. *Platina and Nickel* were made 1 and 2, the solution of the sulphuret of Potassa being 3 as before. In fact, the bismuth or metal of the preceeding experiment was taken out (the platina being left in the solution) and nickel was adjusted in the circuit in its place. The *Platina* was Pos. at first and strongly (as in the case of Iron). The action and current soon fell much and in a few minutes all was neutral and there was no current. On heating the thermo element the circuit was found to conduct well; on cooling all, the needle returned to zero. This is a very good case and parallel to Iron and Platina. The nickel does not appear to become a sulphuret, but like Iron to remain in the metallic state.

5281. What a variety as to conditions of the bodies and of contact we obtain, and yet how subject all are to the simple result of chemical action. Sometimes the metal does not act, but remains metallic. Sometimes it forms an impervious conducting sulphuret; at other an impervious non-conducting sulphuret; at others a pervious sulphuret; but these changes never cause a departure from the strict dependance of the current on chemical action.

5282. *Platina and Lead* were made 1 and 2. Sulphuret was 3 as before. The lead was very Positive at first, but in a minute or two fell and became perfectly neutral, the needle being at 0°. The effect was very surprizing and sudden. The circuit still conducted the thermo current well. This is an excellent experiment. On completing the circuit without the thermo electric element the needle again returned to 0°. This is a good variation. The whole expt. is fine as a proof.

5283. When the lead was taken out and washed, it was found beautifully covered with a very thin pelicle of sulphuret of lead.

5284. *Platina and Gold* was made 1 and 2, Sulphuret of potash as before 3. The Platina was Pos. at first and strongly so. In a few minutes the metals became neutral. The thermo current travelled freely through the circuit, and that being then put out of the circuit, the Platina and gold were found neutral as before.

5285. The first action by which Gold is Neg. and Platina Pos. depends doubtless upon the difference of the state of the Platina which has been continuously and for some time in the solution, and the Gold which goes in from wiping and the air; or it may be an effect of that return action which Platina would shew under something of similar circumstances in dilute S. Acid. But it is an effect which does not belong to the differences of the two metals used, for a piece of platina used for 2 and put in as the Gold was would undoubtedly shew the same action.

5286. These momentary currents are further proofs against con-

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[1] Hereabouts in the MS. there are several obvious errors in the dates written at the head of the pages. These have been corrected.

tact; they shew a momentary difference, a momentary action and a momentary current. But the *contact*, which is *permanent*, does nothing.

5287. Comparing such different metals as Iron, Nickel, Bismuth, Lead and Gold against Platina, we in none of the cases find any thing like a residual action, as if there were powers balanced one against the other, but leaving now and then a little surplus in one direction, stronger or weaker. All comes to a *quiescent* state, shewing I think that in the ultimate condition, no action or force is exerted. It is not a state of opposed tension but of absolute rest. The feeblest thermo force is shewn at once.

5288. And should it be said that the forces are balanced, then let the case be shewn where they are not balanced. Or if that can not be shewn, let it be allowed there is no such force in contact at all; or if there is, that it is always balanced in the complete circuit and can therefore never produce the current in the voltaic pile.

5289. *Platina* and *Palladium* were 1 and 2 and sulphuret of potassa 3. The Platina was Pos. at first (as with the Gold before) and strongly too. The current quickly fell, but after some time it was still equal to 5°, the platina being Pos. At this time the thermo current passed freely, as in the former cases. When all was cold the Platina was Pos., about 3°. Perhaps this effect of the Platina may be due to its power of separating a little sulphur from the solution, as I will describe hereafter (5317). The result is at all events consistent with all the former, and does nothing for contact; for feeble as the residual current is, it is as if the Platina were positive, not the Palladium; and as there is no sulphuret of either platina or palladium formed, it would follow that Platina became Pos. by contact with Palladium. Which is the reverse of the effect of contact between the same metals when 3 is acid.

5290. *Platina and Tin* were 1 and 2, the solution of sulphuret of potash 3. The tin was burnished smooth by a glass rod. The tin was strongly *Pos.* at first, but quickly fell in power. After 10 minutes it was very nearly neutral. On now heating the thermo electric element, no current passed and the circuit was found to be a non conductor of it. The investing sulphuret in fact does not conduct. The whole experiment offers a beautiful case of the cessation of the current with cessation of chemical action, and at the same time presents the variation of a non conducting sulphuret produced.

5291. This case should in the paper probably come before those where conduction continues: For the proof then will rise in force.

5292. *Platina and Antimony* were 1 and 2; Sulrt. Potash was 3. The Antimony was very Pos. and seemed to continue so. After some time the effect was the same, a constant deflection of 60° or more. On taking out the Antimony, the sulphuret on it was found loose, easily washed or wiped off. Thus the sulphuretted solution had access through it to the metal, the formation of fresh sulphuret went on and the current continued. It really offers a fine case and variation in comparison with the former.

5293. *Platina and Cadmium* were 1 and 2. Sulrt. Potash was 3. The cadmium was very Pos. but fell a little, slowly; after an hour the deviation was still 54° or more. On taking out the Cadmium there was an adhering coat of sulphuret on it. As the rod of cadmium was not polished, but rough from the sand paper, it was cleaned, burnished with a glass rod and reintroduced into the experiment. It was at first very Positive. After a while the deflection was 50°, and then all being left for 3 hours, it was still as much as 40°; so that this metal does not come to a state of rest. On taking out the Cadmium the sulphuret was on its surface, partly adhering but partly loose, in small scales and roughness, and the sulphuret of potash had easy access under and through this; so the case becomes like that of Antimony. Perhaps if a weaker solution were used the coat of sulphuret might adhere.

5294. Must try Platina with Copper, Silver, Zinc; also with Cadmium in dilute solution of the sulphuret and also against fresh platina.

5295. Perhaps also as well to repeat some of these actions in solutions of the colourless hydro sulphuret of potassa.

5296. Now proceeded to some experiments w[h]ere Iron was made 1 and contrasted or put against other metals in the same strong solution of yellow sulphuret of potassa.

5297. *Iron and Palladium* were 1 and 2. Sol. Sulrt. Potash was 3. The *Iron* was a little Pos. at first. In a short time the Palladium became very slightly Pos., causing a deflection of about 1°. The thermo current passed, but not so freely as when Platina was 1.

Still, all the proof as to the non efficacy of contact of Iron and Palladium was obtained.

5298. *Iron and Nickel* were 1 and 2. Sulrt. Potash solution was 3. The iron was Pos. at first, but soon very nearly neutral. The thermo current was conducted as before, and very fairly, considering how small the surface of the nickel was.

5299. *Iron and Gold.* Iron Pos. at first—but soon neutral or very nearly so. Then heated the thermo element—its current passed, but still not to the degree that happened when Platina was 1. It seems as if there were some opposing effect exerted by the Iron to the thermo current. The iron is smaller in surface. Still it is clear that Gold and Iron attain and retain a quiescent state, which they keep whilst the circuit is still a conductor.

5300. I turned the thermo element round so as to make its current run in the reverse direction, i.e. the same way as if the iron were Pos.; but there was still the difficulty of getting a free circulation of its current. So that though there appears to be obstruction in the iron, or else where it is in contact with the sulphuretted solution, still it does not seem to depend upon any relation of the iron to the thermo current in reference to its Pos. or Neg. state being affected by it.

5301. The Iron was a flat bar about 0·1 of inch thick and 0·4 of inch wide.

5302. *Iron and Bismuth* were made 1 and 2; Sulrt. Potash solution 3. The Bismuth was Pos. at first; the effect fell rapidly and was soon very nearly neutral. The thermo current then produced an effect, but as before not the full effect, for the needle settled at 9° instead of 45° or more. It was as if the thermo current had caused the iron to react against it and the bismuth and become Positive enough to neutralize much of the effect. All was allowed to cool and came to quiescence nearly, the bismuth being Pos. to about 3° of deflection. Tried the thermo current again; it passed, but feebly. In this experiment the plate of Iron was not only small (compared to former plate of platina), but it was rather far from the bismuth in the solution and the solution itself was small in quantity, not rising high up the plates. All this helped to retard the effect.

5303. Still the result of the whole experiment is that a thermo current can pass, and somewhat freely; whilst the *contact* of Iron and bismuth does nothing.

5304. Now made some experiments with Nickel as 1, it having already been compared with or against Platina and Iron.

5305. *Nickel and Gold* were made 1 and 2; Sulrt. Potash was 3. The nickel was at first a little Pos., but soon became very nearly neutral; in about 5 minutes time the Gold was very slightly Pos. The thermo current was well and permanently conducted. So contact of Nickel and Gold does nothing.

5306. *Nickel and Palladium* were 1 and 2; Sulrt. Potash 3. The Nickel was immersed first and then the Palladium. The Nickel was at first Positive, but in a few minutes the Palladium was Pos. by about 1° of deflection. Then the thermo current was well conducted, but with a little pulsatory start; but this was due I think to the junction of the Bismuth and Antimony having got out of order. The result was a very good one and shews that contact of Nickel and Palladium does nothing.

5307. The Nickel is a small bar, not polished but rather porous; it has been forged, but there are little cavities on its surface. The contents of these may account for the variations of current during the first few minutes of immersion.

5308. Must try Nickel with Lead, Bismuth, Silver, Copper[1].

5309. *Bismuth* has been associated with Platina (5273) and Iron (5302). Now tried it with Gold and Palladium.

5310. *Bismuth and Gold* made 1 and 2; Sulrt. Potash being 3. The Bismuth was strongly Positive; it fell regularly and in half an hour was almost neutral. It then conducted the thermo current well. On throwing the latter out of the circuit and completing the voltaic circuit only, the needle at once came to 0°. Thus the metals bismuth and Gold do nothing by contact.

5311. *Bismuth and Palladium* were made 1 and 2; Sulrt. Potash 3. The Bismuth was positive at first—soon became neutral and then conducted thermo current well. On cooling, the Palladium was a trace Pos.—but in a short time all was neutral. The thermo current was well conducted and its passage did not alter the neutrality of the Bismuth and Palladium when opposed to each other. A very Good Case.

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[1] In the manuscript the words "Silver, Copper" have been added in pencil.

5312. Must try Bismuth with Lead, Nickel, Silver, Copper[1].

5313. Made *Platina* 1; Native crystd. *Sulphuret of Iron* 2; and solution of *sulphuret of Potassa* 3. As a voltaic circuit it was neutral, but the thermo current travelled, being conducted pretty well. So the argument stands good by the experiment here.

5314. Made *Platina* 1; *Galena* 2; Sulrt. Potash 3. There was no voltaic current, but on heating the thermo electric element the effect produced, though sensible, was very small, and not so much as I expected.

5315. *Platina* and *sulphuret of lead* are however well associated where lead was used (5282), for at last 1 and 2 are Platina and sulphuret of lead, the two metals being connected by lead and copper in the metallic part of the circuit (with Antimony and bismuth also). So it is there shewn that these two produce no voltaic current, yet thermo current passes well. Hence their metallic contact does nothing.

5316. *Platina* and *Sulphuret of Bismuth.* The same good results as is shewn by the experiment with bismuth (5273).

5317. When the experiment of Platina and Cadmium (5293) was left for three hours and then dismounted, the platina was found covered with a fine dew or adhering powder of sulphur, as if the sulphur had been precipitated upon it. A glass rod which was in the solution at the same time was also similarly covered. A platina plate which was put into the same solution all night, but not forming part of a voltaic circuit, was found in the morning with a deposition of sulphur on it, but not to the same extent in quantity as the others. This tendency of sulphur to separate in contact with the platina may perhaps occasionally cause a current when the platina forms part of a circuit.

5318. The solution of sulphuret of potassa is of great value as an exciting electrolyte, for its power of forming resulting compounds which are *insoluble* and *yet conductors*; for it thus adds important facts to the proofs of the electro chemical theory. Should be glad to know of some other body doing so.

[1] In the manuscript the words "Silver, Copper" have been added in pencil.

5319. Instead of making 3 sol. Sulrt. Potash for an electrolyte, or a metal for a conductor, may think that if it were such a body as per oxide of lead or per oxide of manganese or a sulphuret of a metal, some effect might be obtained of illustration. Now at pp. 1183, 1184[1] such bodies are there interposed, but no current was produced. Thus there is no trace of effect of contact there.

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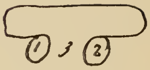
5320. Continued the experiments of yesterday, using a fresh portion of the same strong solution of the *sulphuret of potash for* 3, and metals and sulphurets, etc. for 1 and 2.



5321. Made *Platina and Copper* 1 and 2. The copper was burnished smooth with a glass rod after being cleaned. It became very Pos. and continued so, the needle remaining strongly deflected. On taking out the copper, it was found the sulphuret did not adhere, but easily wiped off in scales. So a continued action and a continued current.

5322. Tried Platina and polished copper in a diluted solution of the sulphuret of potash (1 vol. of the strong + 4 vols. water), but with the same result. The copper remained permanently active and the sulphuret easily wiped off from it.

5323. Made *Platina and Silver* 1 and 2. Strong sol. Sulrt. potash was 3. The silver very Positive and continued so.

5324. *Platina and Polished Zinc* made 1 and 2. Strong sol. Sulrt. Potash 3. The Zinc was strongly Pos.—it diminished very slowly for a time and then kept strong and steady. On taking out the Zinc it was very bright, as if the sulphuret formed was soluble. Try this (5357).

5325. Tried *Platina and Platina* together, to know the relation of the piece in first to that put in afterwards (   ). When both were in and all at 0°, took one out, washed and wiped it and then put it in again; then did so with the other. Whichever remained in was positive to that which was removed and reintroduced. On lifting one out into the air for a few moments and then reintroducing it, it was Negative slightly to the one remaining in, which last was Positive. This is the contrary to what happened on a former occasion with a weaker solution of a different sulphuret (5177, 5127, 5961).

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[1] i.e. par. 5206 *et seq.*

5326. *Platina and Cadmium* were made 1 and 2 in a weak solution of the sulphuret of potash (1 vol. strong sol. + 4 vols. water). The cadmium was polished: at first it was strongly pos.; the effect fell much and in about an hour the deflection was not above 1°, so weak was the action. On trying the thermo current, there was scarcely a trace of its being conducted. The proof that current diminishes as the action diminishes is however perfect ( ).

5327. *Lead* has been compared before with Platina (5282). Now proceeded to associate it with other metals.

5328. *Lead and Gold* made 1 and 2; Strong sol. Sulrt. Potash made 3. The lead was Pos., but fell fast and was neutral in a few minutes. It then conducted the thermo current well. On allowing the thermo apparatus to cool, the needle returned to 0°. So here no contact effect.

5329. *Lead and Palladium* 1 and 2; Sulrt. Potash 3. Just the same as with Gold.

5330. *Lead and Iron* 1 and 2; Sulrt. Potash 3. Lead strongly Pos., but its effect soon went off and deflection diminished. Still it went down slowly by comparison with other cases of lead and the Iron appears to be *actively Negative*. When the deflection was about 8°, heated the thermo pile, but there was scarcely any effect on the needle. There was the same difficulty of passage as yesterday. When the temperature had fallen, the continuous deflection due to the Negative Iron was about 4°. Tried the thermo effect again and found that, though a little of the thermo current passed, there was the same difficulty as before. Being again cooled, the Iron effect was such as by this time to bring the needle very nearly to 0°.

5331. I cannot resist the suspicion that Iron has such an effect on the electrolyte as to be actively negative. Is it possible that this can be from any power it may possess of *attracting a cation from it*, or does it depend upon its giving up an anion, or what?

5332. *Lead and Nickel* 1 and 2; Strong sol. Sulrt. Potash 3. The lead pos.—then diminished and soon nearly neutral. It then conducted the thermo current pretty well. When all cooled, it was more nearly neutral, but still some traces of the current. The result is, that contact of Lead and nickel does nothing—but also that Nickel has a little of that peculiar relation so striking in iron.

5333. As nickel is not a readily oxidizable metal in the air, it rather tends to suggest that the effects of both are due to their power of associating cations with them. As to Iron, may not its mode of rusting have something to do with this? Will Iron, on which platina filings are sprinkled, rust round these filings, it being kept constantly in an atmosphere in which water will not deposit as a fluid on it?

5334. *Lead and Bismuth* 1 and 2; Sol. Sulrt. Potash 3. Bismuth very Pos.—quickly neutral—then conducted the thermo current well. When all cold, needle was at 0° again. Good result.

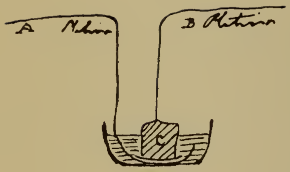
5335. *Bismuth* has been associated with Platina (5273), Iron (5302), Gold (5310), Palladium (5311), and lead (5334); now compared it with *Nickel*, making *Bismuth* 1; *Nickel* 2; and Sulrt. Potassa 3. The Bismuth was Pos., but soon became nearly neutral and then the thermo current was conducted well. When all was cold, the needle was very nearly at 0°; only a trace of deflection. Hence Bismuth and Nickel do nothing by contact.

5336. Used two plates of clean *Iron*, new pieces, in the strong solution of sulphuret of potassa, to ascertain how they would conduct the thermo current. They were 0·1 of inch thick; 0·75 of inch broad, and 1·8 inches in length were immersed in the solution. This surface, with Platina, Gold, lead or other metals, would have conducted the thermo electric current freely. The piece of iron last put in was Negative for a moment to the other and then the whole was neutral. On heating the thermo element I could scarcely get any of its current to pass. The effect was really very bad indeed and very striking in that respect. Must examine this matter of Iron.

5337. In thinking of the bad conducting power, we must remember there were two iron surfaces here; so that if one surface was an obstruction in former cases, two would be more so. May the bad conduction depend upon the surface of the Iron becoming invested with a badly conducting film? It seems very bright and clean, but if it attracts a *cation* to it, it might be so. Will reflection shew any difference? Must examine the whole question well.

5338. *Platina* and *Scale oxide of Iron* made 1 and 2; Sulrt. Potash made 3. The oxide was prepared by taking a plate of iron and making it dull red hot for half an hour in the air—then letting it cool and brightening one part for connexion with the contact wire. The Platina was at first strongly Pos., i.e. the oxide or iron plate was strongly negative. When the deflection was 6°, heated the thermo element and found its current to pass far better than with the clean iron plate. Allowed all to cool and then the deflection was 3°. Heated again and the current was fairly conducted, though not quite so well as by other metals. When again cold the deflection was only 1°.

5339. Thus Platina and Oxide of Iron do nothing by contact. Oxide of Iron appears to be actively Negative (i.e. if the solution did not penetrate to the metallic iron under it). Oxide of iron conducts thermo current into the solution better than pure iron does. If oxide of iron should be found really to have the same active Neg. force as metallic iron, remember also that it is Magnetic.



5340. Took a flat glass, bent a platina plate A so that its end laid in the bottom of the glass; poured in some strong solution of the sulphuret of potassa; placed a folded dry piece of cloth in the solution on the platina plate; put a compact piece of *yellow native copper pyrites* on the cloth so that its upper part was out of the solution and dry; let the end of the platina wire B rest on this, and so, A and B being connected with the Galvanometer and thermopile, had platina and copper pyrites as 1 and 2 with sulrt. potassa as 3. There was no voltaic current, but the arrangement conducted the thermo current very well. Hence no effect of contact here, etc. etc.

5341. *Platina* and *Grey Sulphuret of copper*, being associated in the same way, the Grey sulphuret was very strongly positive to the Platina and continued so. See page 1177 and 1175[1]. The piece of mineral used was an old piece, had been used in such experiments before and was of a different colour.

5342. *Platina* and *Galena* associated in the sulrt. potash—there was no voltaic current and I could scarcely get a sensible thermo current to pass. The galena was not very compact, i.e. it might have fissures, etc. within to interfere with its conducting power.

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[1] i.e. pars. 5189 and 5183.

5343. The various results include the comparison of the

Sulphuret of Lead with	Platina
	Gold
	Palladium
	Iron
	Nickel
	Bismuth
Sulphuret of Bismuth with	Platina
	Gold
	Palladium
	Iron
	Nickel
	Lead and Sulphuret of Lead.
Sulphuret of Cadmium with	Platina
Sulphuret of Iron ,,	Platina;

and the results are all against theory of contact, for no effect of contact can be evolved and set out.

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5344. Platina and silver were made 1 and 2 in a weak solution of sulphuret of potassa (1 vol. strong sol. + 7 vols. water). The silver was Positive strongly and remained so for an hour or more.

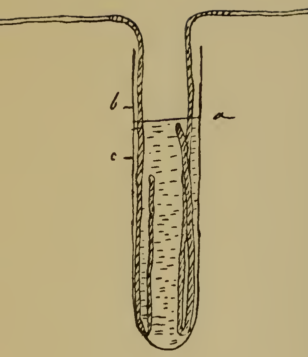
5345. Platina and Native Gray sulphuret of copper were again made 1 and 2 in a strong solution of sulphuret of potassa (5341). The sulphuret was strongly positive and remained permanently so. It was a new piece. Hence it acts powerfully (5189). It changed colour and lustre and evidently underwent a chemical change; it is probably raised to a higher degree of sulphuration, and the same change may not take place in colourless hydro sulphuret of potash. See to that (5183). It is acted on by it and becomes strongly Pos. See 5183.

5346. Some of Keir's sulphuric acid for dissolving silver and not copper was made, consisting of 1 Nitre and 10 strong oil of vitriol. This was some days ago, and now it is clear and crystallization of bisulphate of potash present. It was made 3.

5347. *Platina and Copper* in Keir's acid; the copper was strongly and permanently Pos.

5348. *Platina and Silver* in Keir's acid. The silver was strongly and permanently Pos.

5349. Silver and copper in Keir's acid. The Copper was strongly and permanently Pos.

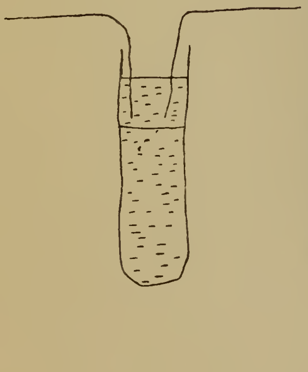


5350. So this acid does me no particular good; the order of silver and copper being the same in it as in dilute Sulc. or nitric acid.

5351. *Nitrous acid*, its conduction, etc. Took a glass tube, size of the sketch[1]; put into it some condensed nitrous acid from distilled nitrate of lead. It was yellow and so free from water and occupied the tube up to *a*. Put in two platina wires and connected them as in former cases with the Galvanometer and thermo element of bismuth and antimony. There was no action on the needle and on heating the thermo element *no current* could pass (to produce sensible deviation).

5352. Put four drops of water into the tube. These acted on and mingled with the Nitrous acid, evolving a little nitrous gas and producing a dark green hydrated nitrous acid (containing now probably a little nitric acid from the action of the water); and this green part occupied about 0·4 of an inch from *b* to *c*. Now the thermo current was conducted with very great facility, and that too though only that part of the platina wires in the green solution could act as conductors. On taking out the wires and then immersing only about $\frac{1}{3}$ of an inch of each into the green acid, the thermo current was well conducted (5456).

5353. After certain other experiments to be described directly, all the acid (green and yellow) was mixed together so that there was but very little water in any part. The colour was now less green or brownish green. The fluid conducted the thermo-current, but not so well as before. The most green is that which conducts best.



5354. Experimented with the most green acid and *Iron* by making one wire platina and the other clean *Iron* and dipping the tips of these into the acid, thus. At first there was a little current, which gradually became very small. Then on trying the thermo current found it was not sensibly conducted. It had every appearance as if the iron were invested by an opposing or non-conducting film, or else had a direct opposing action to the current tending to pass.

5355. Removed the Iron wire and used another, which had been heated in a spirit lamp and covered with a film of oxide. This is both Schonbein's oxidized iron wire and scale oxide of Iron. This with the platina produced no voltaic or permanent current, but on heating the thermo-element its current was found to pass with great facility.

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[1] The diagram has been reduced to $\frac{3}{4}$ scale.

5356. This difference between *inactive iron* and *oxidized iron* as to the conduction of the thermo current seems to point to a distinct state of the two; seems to imply that the iron is not inactive because of a state or film of oxidation.

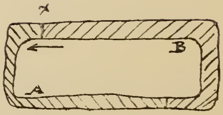
5357. Sulphuret of Zinc (5324) is soluble in the strong solution of the Sulphuret of Potassa. I put a drop of muriate of zinc into a glass tube, added a drop of the sulphuret of potash and stirred; immediately a thick magma of sulphuret of zinc was formed, but on adding much more of the solution of sulphuret of potassa, the precipitate was gradually dissolved and all became clear.

5358. Blende does not conduct the thermo-current.

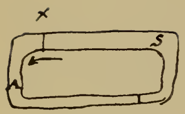
5359. With reference to the peculiarities of Iron and its peculiar mode of rusting in spots, at which time perhaps its other surface is invested with a cation: took a clean plate of Iron and put on to it here and there some fine particles of Platina; and then set all aside in a cupboard, where I do not think the water of the air will ever deposit as a *fluid* on the metals—wishing to see what sort of action will go on in this case (see 6078).

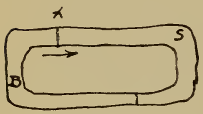
5360. *Thermo contact.* If contact of metals does any thing, then hardly doubt that what is called thermo electricity is due to same force, i.e. to disturbance by local heat of the balanced forces of the different contacts in a metallic or similar circuit considered at common temperatures. Those who quote thermo effects as proofs of effects of contact must admit this.

5361. May then assume that heat either increases or diminishes the electromotive force of contact, i.e. if A be antimony and B bismuth, heat applied at x causes the current to pass in the direction of the arrow. Now if, according to the contact theory, Bismuth in contact with Antimony tends to become Pos. and the Antimony Neg., then heat diminishes the effect; but if the tendency of Bismuth is to be Neg. and Antimony Pos., their heat increases the effect. But how are we to decide which is which?



5362. Let us for that purpose go to the Voltaic circuit. There, Antimony and Bismuth come close together in the middle of the series; so that tells but little, though it makes Bismuth Pos. to Antimony. But in the thermo series they are the extremes, being as different as they can be. How does this consist with the contact theory in the Voltaic pile?





5363. Again, if silver and Antimony form a thermo series and the junction *x* be heated, the current there is from the silver to the Antimony. If silver and Bismuth form a thermo series, and *x* be heated, the current is from the Bismuth to the silver. But in the Voltaic series, when an ordinary acid excites the arrangement, it is from the silver to both the Antimony and the Bismuth, and that very strongly. How little therefore metallic contact can do—if it can do any thing in these cases.

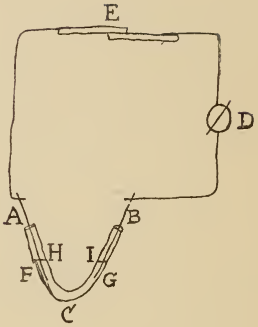
5364. So by the heat series, Tin and Lead are more *negative* to Zinc than Silver is; how does this agree with voltaic effects? Platina is *Positive* to Bismuth. So is Silver and Iron. Zinc is Negative to Antimony. So is Lead and Tin, and especially Bismuth above all other metals—and a great number of such irregularities come out, which can only be accounted for by assuming a specific effect of contact of the acids for each metal, which is not only one unlike Metallic contact in having a balanced state in the complete circuit, but is in no relation to it as to the order of the substances considered. Thus Bismuth and Antimony, which are greatly removed thermo electrically, must have this extra character of acid contact very greatly developed to make them a feeble voltaic combination; and with respect to silver, which stands between tin and zinc thermo-electrically, not only must this happen, but how great must the effect of this its incongruous contact be to overcome so completely as it does the differences which the metals tend to produce. In fact, what evidence for contact remains, since it is thus referred to the acid, and made not only to vary uncertainly for each metal, but to vary also in direct conformity with the variation of chemical action?

28 OCTR. 1839.

5365. Expts. on Inversion or change of current or production of it by altering the force of chemical affinity without change of contact and without (in many cases) any metallic contact.

5366. As heat exalts chemical affinity, I thought it probable that a circle of one metal and one fluid might produce a voltaic current when one of the contacts of metal and fluid was *heated*; and if this could be done with fluids, etc. which either did not generate or could not conduct a thermo-current produced by Antimony and Bismuth, it might be concluded the effect would result from pure chemical affinity—contact doing nothing.

5367. The form of experiment was this: C was a glass tube bent as represented; the limbs were about 3 inches long and the tube $\frac{1}{3}$ of an inch in diameter; it was supported on a ring so that either the part F or G could be heated by a spirit lamp. A and B are clean wires, either of the same or of different metals, and are to be compared as to the action of the fluid in the tube upon them. B is connected by a copper wire with a Galvanometer D (delicate); that at pleasure with a thermo electric element of Antimony and bismuth E; and that by a copper wire with A to complete the circuit. Or the thermo electric element could be thrown out of the circuit and the latter be completed without it.



5368. In making the experiment, the fluid to be used was put into the tube C. The wires A and B were carefully cleaned with sandpaper, etc. and sometimes burnished smooth by a glass rod. It was very easy to heat F or G separately, and when required to cool the heated part it was also easily done, by pouring a little stream of cold water on at H or I from a jug into a basin below: a minute or two sufficed for that purpose. After an experiment, the tube was well washed out and drained on bibulous paper for the next experiment.

5369. In the first experiments, made the same metal 1 and 2 and *dilute Sulphuric acid* 3. For this purpose, about one by weight of oil of vitriol was mixed with 80 or 90 times its weight of water, and different portions of this *same solution* used for the successive experiments now to be described.

5370. The metals were wires, about the $\frac{1}{20}$ of an inch or more in diameter, and when two pieces of the same metal were compared, they were (with the exception of the platina) two contiguous portions of the same original piece of wire, so that they might be as like in every thing as possible.

5371. *Platina; Platina; dil. Sulc. Acid.* There was a little variation of the needle on the first immersion—indeed there almost always is in such experiments. It is nearly impossible to make the circumstances so exactly alike as to have no first effect of this kind. In such cases therefore, it is the permanent effect (which comes on generally quickly) that we must look to.

5372. The needle soon settled at 0°. Then heated A to the boiling point (being the left hand Platina, etc.). It became in the least degree *Positive.* Cooled it and heated Platina B, etc.: then it became in an equally small degree *Positive.*

5373. On cooling A and B and then heating the thermo element, I could not be sure that any sensible portion of its current was transmitted, so small if any was the effect.

5374. Hence it would appear that this diluted acid is too bad a conductor to transmit any portion of a thermo electric current, unless it be far stronger than that from a pair of Antimony and Bismuth; that therefore, if the little current shewn by heating the platina is of a thermo electric nature, the acid and metal is a far more powerful combination than Antimony and Bismuth; and also that, if of this nature, it is scarcely sensible by this delicate galvanometer.

5375. It is also true that the heated Platina and acid have very little if any chemical action on each other, and in conformity thereto, that the heated Platina is *very little* if any thing Positive to the cold. This accords with general condition of chemical action.

5376. Whether, if there were any thermo current, it would be in the same direction as the chemical current, I do not as yet know. Must ascertain that (5519). If there were, it would seem to be that *Platina is to acid* as *Bismuth to Antimony.*

5377. *Silver; Silver; Same dil. S.A.* No action at first. On heating B, it became the least trace Positive. On cooling it, it returned to 0°. On heating A, it became the least trace Positive; and on cooling returned. The smallness of action here still consists with the state of the chemical affinity and the experiment therefore runs with that with Platina.

5378. *Copper; Copper; same dil. Sulc. Acid.* B rather Pos. to A at the first; indeed considerably. Then heated A and it became Positive, a little only, i.e. 10°. When at 10° of A Pos., heated B, but it did not become Pos., but more negative, and at the boiling point this was not diminished. On cooling B, its negative state diminished until the needle came to 10°. Then heated A, and it became *Neg.* about as much as B before; on being cooled this diminished. I think that when the needle was at 10°, both wires were probably quiescent and that no chemical action on the copper was going on. That the heated metal became negative was decided. Can this be a thermo effect? I do not think it was chemical, and in that respect copper is like Platina and silver in this dilute acid.

5379. *Iron; Iron; Same dil. S.A.* Wire A was Positive at first and continued so. Heated B, and it gradually passed from Neg. to Positive, attaining a deflection of 35°. Cooled B, and the needle went back to 0°. Heated A, and it in turn became Positive 35° or more—cooled it and the needle returned to 0°. This is a most excellent result. The effects could not I think depend on thermo electricity—far too great.

5380. Must remember that though the series of thermo electric exciters is different to the volta electric order, yet it is consistent with itself, i.e. that if Iron and Antimony be weak to each other and Bismuth be strong with Iron, it will also be strong with Antimony. So it is unlikely that the Sulc. Acid would be very strong to Iron and very weak to silver, which is not far from it thermo electrically speaking. Nor is it likely that it would be nearly alike to Platina and Silver, which are far apart in the thermo electric series.

5381. *Lead; Lead; same dil. S.A.* The wire B was Positive at first, but after a while fell to Pos. 5°. Heated A and it became Positive full 30°—on cooling it it fell to 0°. Then heated B and it became Pos. to about 15°. On cooling B it fell through 20° or to A Pos. 5°. This is a very fair experiment as to the effect of heat in increasing chemical action and the current at once.

5382. *Tin; Tin; same dil. S.A.* Needle steady and at 0°. Heated A and it became a little Positive, about 10°—cooled it and the effect fell to 0°; heated B and it became Positive—cooled it and it fell again. The deflection was but small here with Tin and this dilute Sulphuric acid—but consistent with former results.

5383. *Zinc; Zinc; same dilute S.A.* Needle steady and no deflection—was at 0°. Heated A or left hand zinc: it became at first a little Positive and then well Negative and continued so. Heated B and then the deflection fell, as if B became gradually negative or rather less Positive; and the needle was nearly at 0°. On cooling all, B was permanently Pos. and A Negative, as if at the outset A had had some precipitation on it of copper, or some other circumstance making a permanent difference.

5384. As the liquid boiled at last, would the bulk of bubbles on the heated wire make the contact less there and so produce a difference? Think not.

5385. Next worked with metals using *dilute Nitric acid* as the Electrolyte. The mixture was about 1 part by volume of pure nitric acid and 50 of distilled water. It was the same for all the following experiments.

5386. *Platina; Platina; dil. N.A.* Needle steady at 0°. Heated A and B alternately, and the one heated was Positive to the other, but still hardly sensibly so. The thermo current of Antimony and Bismuth did not pass. The effect produced may be thermo electric or it may be chemical; either way it shews that, where there is little or no chemical action, there is little or no current. It shews that the mere effect of heat, if it produce a current at all, produces one almost insensible.

5387. *Silver; Silver; dil. N.A.* No action, all steady at 0°. Heated A—no sensible change: cooled it and heated B—no change. This a very good experiment as to non effect of heat and non production of a current when there is no chemical action.

5388. Supposing the effect with Platina be taken as a thermo-effect: then it would appear from the silver result that Acid is, as a thermo-motor, at the bottom of the scale, or at least near to silver, and therefore the same as or even above Iron; and in that case it is not likely that the dil. S.A. would be so far below iron as to produce the effects it has shewn.

5389. I made an experiment with Silver in diluted N.A. of much higher strength than this, for which, see notes further on (5447).

5390. *Copper; Copper; dil. N.Acid*, same as before. A little motion at first, but needle settled at 0°. Heated wire and acid B—it became Positive 10°; cooled it—it became a little Negative. Heated A—then it became Positive 10° or thereabout; cooled it and all came to 0°. There is here very little action by heat, but it is of the right kind.

5391. *Iron; Iron; dil. N. Acid* same. Some oscillation—A at first Positive—this gradually fell and B became Positive and continued so rather steadily—after a while this fell, but with little slow variations of the needle, indicating the active opposed tendencies of the two wires in the acid. Whilst B was a little Positive I heated A—this rendered A strongly Positive and B Negative. Cooled A and the effect went down entirely, leaving B a little more Positive than when heat was first applied to A; but a part of that excess gradually went off, and all came to the state at the beginning of the heating of A, i.e. with B a little Positive. Then heated B and it became very Positive in turn—cooled it and that effect fell, leaving B a little Negative, which surplus effect gradually went off, as it had done before with A on cooling it. The effect of heat is very excellent and striking, as it was also with iron in dil. S. Acid. On taking out the irons they were found considerably acted upon.

5392. *Tin; Tin; dil. N. A. same.* At first a little motion, A being Positive, but after a while settled at 0°. Heated B, and this made it a little Positive—on cooling B it continued Positive, the needle not moving—heated A: it then became a little Positive as B had done—on cooling it, it became rather more Positive. Again heated B, but still A remained positive. The wires had taken a permanent condition. On taking them out it was found they had both been a good deal acted on, and when wiped a grey powder wiped off from both. Whether this was an oxide of tin or crystals of tin or other metal separated, still it was likely to cause an irregularity of action (5465).

5393. Repeat this with weaker acid and also take care of the place of the ends.

5394. *Lead; Lead; same dil. N. A.* Disturbance of the needle—A positive at first—settled nearly to 0°. Heated B: it became *Negative* about 15°—cooled it, it sank to about 7°. Heated A, which rendered it *Negative* about 19°; cooled it, which returned it to about 3°. Heated B again and it now became as Negative as before (5470, 6081).

5395. This is a very remarkable action of Lead. On taking the metal out, found it had been a good deal acted on, and the surface was dissected and crystalline.

5396. *Zinc; Zinc; same dil. N.A.* (5475, 6082). Wavering at first and A stood Positive at 14°. Heated B, and the needle went back 23°, B becoming Positive 9°. Cooled B, and the needle went back these 23° to A Positive 14° or thereabouts. Heated A; at first its positive force increased, but then suddenly it became strongly Negative to 50° or more. On cooling A, 40° or more of this Negative effect went down. Reheated B; it became sensibly more Positive. Reheated A; it became as before very negative.

5397. There must be some accidental touch of other metal or some circumstance of that kind here, for the two zincs A and B are not alike. Then it is also probable that the circumstance, whatever it is, of one of the zincs here, as of the zinc A, is the same in nature as that on both the Leads in the former case.

5398. Thus far the comparisons have been between two pieces of the same metal in the same acid. Now compared two pieces of *different metals* in the same acid.

5399. *A Silver; B Palladium; same dil. N.A.* Silver a little Positive at first—heated the Palladium—it became a little less Negative, but not much. Cooled the Palladium and heated the silver. Now the silver became a little more Positive. There was very little change either way—the effect was not striking, except as shewing that mere heat did not do much, if anything.

5400. *A Silver; B Copper; same dil. N.A.* (5483). Little motion at first but settled at 0°. Heated Silver and it became Negative somewhat, about 12°, gradually diminishing: cooled it and it became Positive 4° or 5°—heated the copper and there was no sensible alteration—heated the silver again, and again it became Negative.

5401. Thinking these action[s] might depend upon accidental access of the heat to the junction of the silver wire with the copper connection, I purposely heated that, but such heating did nothing.

5402. The effect is in the solution at the Silver and I must make it out (5485).

5403. *A Iron; B Tin; same dil. N.Acid.* The tin was at the first moment Positive—then the Iron became strongly and permanently so to 45°. Heated the tin: at the boiling point it overcame the Iron and was Pos. fully 20°. Cooled it and the needle went back gradually 40° until the Iron was Pos. 20° and still rising. Heated the Iron and it rose in Positive force, reaching 40°. Cooled the Iron and it lost its Positive force, the Tin becoming Positive full 60°, whilst the Iron was still warm; but this diminished gradually and when the Iron was cold the Tin was Pos. 30°, still diminishing. Warmed the Tin: it then increased in Positive force. Cooled Tin and warmed the Iron; then the iron was much most positive. Cooled the Iron and it became Negative–the tin becoming Pos. when all was cold as before.

5404. There is a strong and evident antagonism of the tin and iron forces here, but heat always gave the victory to either one or the other. When taken out, both the Tin and the Iron were found much acted on. A dark powder wiped off from the Iron and a gray one from the Tin. *A Good result.*

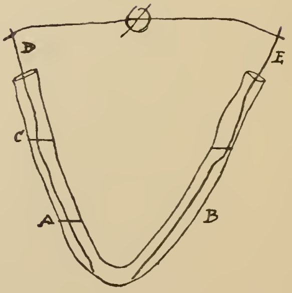
5405. *A Tin; B Lead; same dil. N. Acid.* The lead strongly Positive: equal to 60°–did not alter the effect sensibly by heating either the Tin or the Lead. The affinities too strong and different to have that difference altered by the action of heat, in any sensible degree.

5406. *A Tin; B Zinc; same dil. N. A.* Zinc permanently and strongly Positive. Heating either A or B made no difference.

5407. *A Lead; B Zinc; same dil. N. A.* Zinc strongly Positive. Heat to Lead did nothing.

5408. There are two important precautions in these experiments which should always be attended to. When the wires are cleaned from one experiment for another, the extreme end should also be as well cleaned, or else cut off, for from the form of the apparatus (a tube), the extreme ends act more powerfully in proportion than any other part. Hence they especially should be in a proper condition.

5409. Again, it is necessary to bring the end of the wire into the heated part of the fluid. Suppose D, E two wires of silver in the acid in the tube and that the acid be heated from A to C. In that case it is not the hot part of D between A and C which by the Galvanometer is compared to B, but the cold part below A, and to compare the hot and cold states fairly, the end of D should have been originally between A and C. Even raising that end into the



hot part is better than the state delineated, and I have often seen that, though the extent of bad conductor is increased by so doing, so as to retard more any current, yet the current has increased by such change.

5410. I now changed the electrolyte, using *strong Nitric acid* instead of weak (5606). It was pure pale acid, not quite free from nitrous acid but nearly so. It was very strong fuming, and not acting on iron after the first moment, i.e. not acting seriously. Of course fresh portions of the same acid were used for the successive experiments.

5411. *Platina; Platina; Strong N. Acid.* Little motion at first, then rested at 0°. Heated B and it became *Neg.* 10°—cooled it and it went back to 0°. Heated A: it became Negative about the same—cooled it and it went back to 0°. There was always I think a return in these delicate actions to a degree a little on the further side of the expected or previous point. This is perhaps a reaction back of the two plates which, having had a current passed through them, tend to produce a contrary current, so that when the original force is taken off by cooling, it produces a certain effect (5799).

5412. The thermo current of Bismuth and Antimony does not pass well through this acid, but is sensible. It at the end of the above heatings was perhaps nearly the same in quantity as heating either Platina A or B in the acid.

5413. Is the above a thermo effect or what? It is the contrary of the effect of Platina in dilute N. Acid.

5414. *Iron; Iron; Strong N. A.* There was disturbance and A remained Positive. Heated B, but not to violent action, and it became well Positive. Cooled it and it lost its power, A becoming as Pos. as before. Heated A: it became more Positive, and being cooled, fell again to first state. Heated B again and it now became Positive; cooled it and it fell as before to normal state. Heated A to boiling, but not to the point of violent action on the iron: A became very Positive—but on cooling it, it went back as before. That side of the tube was now yellow from the quantity of iron dissolved. Heated A again until boiling: same effect as before—cooled it and all went down.

This a very striking and good result.

5415. *Palladium; Iron; Strong N. Acid.* Iron was Pos. to the

Palladium and continued so 15°. Warmed the Palladium until the chemical action evident there by the brown nitrate of Palladium produced, but I could not alter the deflection; the iron remained steadily Pos. 15°.

5416. *Silver; Iron; Strong N. Acid.* Here the Silver was very strongly Positive. Heated the Iron side to boiling, but the silver remained as Positive as ever.

5417. *Copper; Iron; Strong N. Acid.* Copper very Positive and remained so when the Iron was heated.

5418. *Silver; Palladium; Strong N. A.* Silver very powerfully Positive. Heated the Palladium until it dissolved, producing a brown solution, but still Silver continued as Positive as before.

5419. *Silver; Copper; Strong N. A.* Copper powerfully Positive. When invested with crystals and the apparent chemical action on it ceased, still it was most Positive and powerfully so. Heated the silver until strong action on it, but could not alter the relation of the two.

5420. *Silver; Lead; Strong N. A.* First, Lead strongly Positive to silver—in a moment Silver very strongly Pos. to the lead. Then deflection went down until at 0°. Lead grew Positive and rose up to 40° or more, the needle advancing with unsteady motions. On moving the Lead in the acid it became very strongly Positive, but immediately after, the silver became Positive again—and then the lead. The lead is most Positive, but it becomes invested with something (crystals) which retard or prevent chemical action, and then it is Negative to the silver. Moving the silver in the acid did nothing or scarcely any thing, but every repetition of the moving of the lead produced the same effects as before.

5421. By looking at the lead whilst in the acid, examining it with a lens, the investing crystals could easily be seen, and these account sufficiently for the variations.

5422. *Lead; Copper; Strong N. A.* Lead at first strongly Positive. The[n] the Copper was most Positive strongly and a crust of crystals formed on it. This action gradually fell and Lead became most positive and continued so. On rubbing the copper on the edge of the tube, so as to remove part of its crystalline crust, the needle fell to 0° on its reimmersion; but gradually the lead rose Pos. again to 30° or more.

5423. *Lead; Tin; Strong N.A.* Tin very strongly Pos. to the Lead—continues so—no change.

5424. Now changed the Electrolyte again and in place of either strong or dilute acid, used a solution of caustic *potash*. It was the ordinary solution, not particularly pure, and weak in strength, S.G. . (5617).

5425. *Platina; Platina; Sol. Potash.* No first action. Heated A, but no sensible deflection—cooled A and heated B; there was a trace of deflection as if hot B was Positive. This may be thermo effect; whether that or chemical, effect is very small, and accords with all the other results. It shews no difference between acid and alkali as to mere effect of contact.

5426. *Silver; Silver; Sol. Potash.* B Pos. at first—soon settled to 0°. Heated A: it became the least degree Positive, but even at the boiling point there was no sensible chemical effect or deflection. Heated B: no deflection. Certainly this and such in Electrolytes not acting on the metals are excellent results.

5427. *Iron; Iron; Sol. Potash.* No action at first. Then heated A and it became Positive. Heated B and at first moment it became more negative, but in a moment it became Positive—with the exception of that effect the hottest Iron was Positive to the colder, but only in a small degree.

5428. *Copper; Copper; Sol. Potash.* No motion at first—all steady and at 0°. On heating A it became at first Neg., and then strongly Positive as the fluid began to boil. On heating the side B it became Negative, increasing the Pos. deflection of the hot A; but at the boiling point became Positive and the needle went to the other side. Is the first thermo electric? Whatever it is, its contrast with the second or chemical effect is most strong and beautiful (6085).

5429. *Lead; Lead; Sol. Potash.* Wavering effect—A a little Pos. —heated B and it became very Pos.—then heated A, and when nearly at the boiling point it became Pos. in turn and the needle remained on that side. Thus heat gives the Victory to the acting side.

5430. The lead was a good deal acted on.

5431. *Tin; Tin; Sol. Potash.* Much deflection, and when left, A remained Pos. about 20°. Heated B, and at a certain temperature (not at first), B became strongly Pos., so that needle went to 50°

on the other side. Heated A and then the needle returned and went in the opposite direction. This is a very good result as to the action of heat. Both the tin wires were acted on strongly.

5432. *Zinc; Zinc; Sol. Potash.* Action which settled to a certain degree. Heated one side: it became a little more Positive—heated the other side and it rose in Positive power. The effect of heat here evident, but not very great.

5433. Now used a dilute solution of the *Sulphuret of potash* solution. It consisted of 1 vol. the strong solution before described (5263, 5268) and about 18 vols. of water.

5434. *Platina; Platina; dil. Sulrt. Potash.* Disturbance; settled with A a little Pos. Whichever was heated became a little Pos. to the other—but I must try this with better Platina wires. Effects of heat very small indeed. I think the wires differ a little in character.

5435. *Iron; Iron; dil. Sulrt. Potassa.* A little disturbance, but soon at 0°. Heated A, but needle did not move sensibly—cooled A, no change—heated B, no change sensible. When the iron was wiped, a dark substance came from off both on to the cloth, as if there had been some action.

5436. *Silver; Silver; dil. Sulrt. Potash.* Little oscillation, but needle soon at 0°. Made A hot and it became in the least degree Positive—cooled it and needle was at 0°. B was heated and became a little Pos., but difference was very small. Silver was much acted on and invested with sulphuret.

5437. *Copper; Copper; dil. Sulrt. Potash.* Needle shook about much and A was very Positive—both much acted on in the fluid—force gradually fell—when A was Pos. 40°, heated B, and this undid the effect and made B moderately Positive. On cooling B, its effect did not go down, and when cold it was still Pos. 40°. Heated A, and when its end (5409) was brought into the hot part it became *Positive*. Lowered the end again into the cold part and the state fell, i.e. the Galvanometer changed. Moving the end about much in the cold part below did not cause any effect, but putting it into the hot place produced an effect at once. Whichever was hottest was Positive to the other.

5438. On putting the Antimony and Bismuth element into the circle, found this solution could conduct a little of its current, equal to about 4° or 5°.

5439. *Tin; Tin; dilute Sulrt. Potash.* A little disturbance, but soon at 0°. Heated A: it became at first a little Pos. and then came to 0°. Cooled: it continued still at 0°. Heated B: it became a little Positive and then came to 0°. Cooled it: it still remained at 0°.

5440. *Lead; Lead; dil. Sulrt. Potash.* Neutral. Heated A: it became a little *Negative* and remained about 5° so. Cooled it: it diminished to Neg. 2°. Heated B: it first gave trace of Positive and then of Negative state about 5°, and remained at 2° or 3°. Again heated A; no trace of action now. Perhaps the effect at first is due to a reduction of a film of oxide of lead. On taking out the leads there had been strong action on both. They were quite black, etc. etc. (6086).

5441. *Zinc; Zinc; dil. Sulrt. Potash.* A little action; soon settled at 0°. Heated B: it became *Neg.* strongly and stood at 45°–being cooled, it sank 55° to A Pos. 10°. Then heated A and it in turn became Neg., going through 55° or more. On cooling A this effect went down (6087).

5442. This looks very like a thermo effect–it is the reverse in direction to any expected chemical effect, and must be examined well and correctly referred to its cause.

5443. On heating the thermo electric element of bismuth and antimony, its current did not sensibly pass the solution, so small was the effect. Then whilst this thermo element was in the circuit, it before having been out, heated A again. It instantly became Negative by about 15°. On cooling it, the needle returned through 25°, stopping at A Pos. 10°. Heated B: it became Neg. 40° more, stopping at A Pos. 50°, and on cooling it the needle went back 35°, stopping at A Pos. 15°.

5444. The effect of heat is clear and distinct, though a little permanent deflection remains. It does not appear to be thermo electric, unless such a current, so produced, be very much stronger than the Antimony and Bismuth current; yet how can it be chemical action except it be reduction? I must investigate this curious point. Is it possible the heated metal could be taking Potassium from the sulphur? If so, it ought to become more powerful in acids or water, etc. The Zinc[s] look very clean when taken out.

5445. *Silver; Copper; Dil. Sulrt. Potash.* Copper Positive–

vibrated—effect gradually fell, silver remaining bright. At last it came to 0° or nearly so. Then warmed the silver—it tarnished and became Positive 50°—cooled the silver and it went back to Pos. 15°—warmed the copper and it became Positive 40° or more, the needle moving through 55°. *This is a good experiment.*

5446. Began a few experiments on the effect of diluting the electrolyte on one side, for this often affects chemical affinity, and yet can hardly be supposed to affect the force of contact in the same direction. Thus, Silver is more powerfully acted on by dilute than by nitric acid; yet the effect on contact of acid and silver can hardly be supposed to be equally affected, if at all. Would expect effect of contact to be greatest at the undiluted acid.

5447. Made an acid: 3 vols. Nitric acid strong and 2 vols. of water. This, with A and B silver and silver, acted much more strongly than the Strong N. Acid (5448). B was very much more Pos. than A, yet were two pieces of the same wire. Heated A until chemical action at it was very strong. Still B remained Pos. strongly. There was no reversion and the needle remained at 90°. These actions were much too powerful for heat merely to govern them.

5448. *Silver; Silver; Strong N. A.* At first the needle jumped much—then A was Positive. Then B became Positive and kept moving about—after a while nearly neutral but tending to move. Then put a drop or two of water on the acid at B side; immediately A became Positive 40° or more. Then put some water on A side and instantly B became Positive.

5449. There was now water or rather dilute acid above, both in A and B, and strong acid beneath; and it was easy to lift the wires up so as to bring their respective terminations into the weaker acid above. On doing so in various ways, that wire whose *end* was in the dilute acid was always positive, and well so, to that which was in the strong acid below. *Good.*

5450. Must repeat to see the first reverse deflection and make out its cause.

5451. *Iron; Iron; Strong N. Acid.* Action as before described (   ). When all quiescent, put a drop or two of water on the acid in B so as to dilute it. B became instantly a little Positive, but there was as yet no direct action on the Iron. Warmed the diluted acid a little—a feeble action quickly appeared on the iron at the contact of the acid and water, and instantly that wire, or B, became most powerfully Positive to A. Good effect of dilution. What can this be but chemical action?

5452. *Iron; Silver; Strong N. Acid.* The silver was strongly Positive, and heating the iron till the acid boiled on it did not alter the relation of the two. Silver as positive as ever. Put a drop of water on the acid round the iron. Still Silver powerfully positive. Warmed A or the iron side; very violent action came on at that part and the acid, etc. boiled, evolving much Nitrous gas; yet still the Silver remained positive and the needle was not disturbed.

5453. In this case the lower part of the iron wire passed through the weak acid into the strong acid beneath, and was Negative both to the silver and to the upper part of its own wire, so that the iron action might be considered as in a certain respect local, i.e. confined to the tube limb A. To prove this, cleared out the tube, refilled it with fresh Strong N. Acid, put in the Iron and silver wires and then put a drop or two of water on to the acid round the iron. Then when *both* ends of the iron and silver wires were in the strong acid, the *Silver* was *Positive* strongly; but when the end of the iron wire was drawn up into the dilute acid, the *iron* was very powerfully *positive.*

5454. *Iron, Iron and N. Acid strong.* If top of acid in both limbs be diluted, then the iron in the dilute acid will be Pos. to the other.

5455. *Iron and Silver in N. Acid Strong.* If tops diluted in the same way, then whichever is in the dilute acid will be Positive to the other. So here the effect of contact goes for nothing—all depends upon the chemical action, and that either varied for the same metal or for different metals beautifully.

5456. Now wrought with *hydrated Nitrous acid* as the Electrolyte (5351). Made a mixture of about 1 vol. Nitrous acid and 1 vol. water. It becomes cold on mixture and some nitrous gas is evolved; perhaps some nitric acid is formed. This was put into the bent tube and Platina wires inserted, the thermo electric element being in the circuit. This element was heated and the liquid found to conduct the thermo current very well.

5457. *Iron, Platina,* and the *above green N. Acid.* The Iron was at first Positive, but soon became quite neutral and the needle stood at 0°. Then heated the Antimony and Bismuth element and found that the arrangement conducted the current only a little—it was scarcely sensible. There was great obstruction compared to what happened when both wires were Platina. The iron somehow introduces a great and positive obstruction.

5458. Now made it *Iron*, *Iron* and the *same Nitrous acid*. The wire last put in was for the moment Positive to the former—but soon the needle stood at 0°. Then the arrangement did not sensibly conduct the current of the thermo electric element when that was heated.

5459. Must make out the history of Iron.

5460. In reference to Henry's results and mine on dynamic induction, see Reis' paper in Poggendorf's Annalen for 1835, p. 55 of No. 5[1].

5461. See also Savary's results as to the magnetization of needles in reverse directions in the Annales de Chimie.

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[1] Query P. Riess, Poggendorf's Annalen, 47, 1839, p. 55.

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5462. Went on with experiments on effects of heat on one metal of a pair in dilute acids, and first for the series in dilute Nitric acid; being a part of the same acid as that used in the former cases (5385).

5463. *Gold; Gold; Dil. N. A.* No action—moved first A and then B in the acid—no motion of the needle. Heated A: it became a little negative, about 3° only, scarcely sensible—cooled it and it went back to Neg. 1°—then heated B and it in turn became Neg. about 2°, i.e. the needle moved through 2°. On cooling B, this effect went back again. So when Gold is associated with Gold, both being pieces of the same wire, it appears to become a little negative by heat. Is this an effect of thermo electricity or is it of the kind to be mentioned (5485) when two different metals are associated? If thermo-electric, then it is in the reverse direction to the effect produced by heat on chemical action, and tends to set that forth in a clearer point of view.

5464. *Copper; Copper; same dil. N. A.* (5390). A little motion of needle, A a little Positive. Moved A in the acid, no effect—moved B in the acid, no effect. Heated A: became the least trace more Positive than before—cooled it and this effect fell. Heated B, and it was distinctly a little more Positive than before—cooled it and it fell again. Moved A in the acid and it became a little Positive. Moved B: there was no sensible effect. All the effects are small here.

5465. *Tin; Tin; same dil. N. A.* (5392). A little oscillation—then at 0°. Moved B: it became Positive the while—when still it fell. Moved A and it became Positive in turn to about the same degree, i.e. about 5°, and fell again when quiet. Heated B: it became Pos. up to 13°—removed the lamp and whilst hot the needle went back to 0° nearly. Then moved B and it again became Pos. and went back when left at rest—cooled it and all was at 0°. Moved A and it became Negative rather. Heated A: at first it was a little Negative and then Positive to 8° about.

5466. At present I think that first effect of motion before heat was applied was the consequence of carrying the tin into a fresh portion of solution, able to act upon it with more power than that which had been formed against it—it was in a degree the comparative effects of an old and a new solution.

5467. The effect of heat would consist not only of this change of solution by the current formed, especially during the heating and the boiling, but also of the increased chemical action brought on by high temperature, i.e. increase in force of affinity.

5468. When all was cold after the heating of B, moving A made A become a little Negative. This effect appears to depend upon the circumstance that the previous currents had been with A Negative, under which circumstance it had accumulated around it such substances, or had taken up such a state, as to make it tend to form a counter current (a pretty universal effect); so that when the needle was at 0°, it was the balance of two forces, one of which, that depending on the solution associated with A, could be diminished by changing the solution. This the motion did (and the first effect of heat would do the same); and so it became a little Negative to the other with which no circumstance had been changed.

5469. It is this associated state of the fluids at the Neg. metals which, when the exciting cause at the other metal is diminished, sometimes makes that which was Negative pass the 0° point and shew a positive power; or if the Negative in turn be moved or heated, makes it become more Positive than it apparently ought to do.

5470. *Lead; Lead; dil. N.A.* (5394). Little oscillation—A Pos. about 8°—moving B made B for the moment Positive to 12°, and when quiet this returned to A Pos. 8°. Moved A in the acid and it increased to Pos. 13°. Now heated A: it became a little more Pos. as the heat rose, but being left to itself to cool in the air, A became Negative to 45°. On cooling A by water (5368), this Neg. state fell to 30°. On moving A in the cold acid, the rest fell and A became Pos. 4° or 5°. On moving B, which had been quiet all this heating time, B became Pos.; and on resting went back. On heating B it became Positive; and then, even whilst boiling continued, it became a little Negative, and as it stood quiet, the source of heat being removed, this increased to Neg. 28° or 30°. Cooling by water diminished this a little (probably by causing currents within); and moving B diminished part of the remaining force. Moving A increased its Positiveness. On taking out the lead, there was a black deposit on it which wiped off. This is probably copper and lead, and must hold a strong film of the solution on the surface of the metal (5394, 6081).

5471. I think the Neg. effect must be due to the exhaustion of the film of acid on the surface of the lead—more quickly exhausted by heat than by common temperature—the effects of motion are to remove this in a greater or smaller degree. All seems accountable this way. The effects of heat on the mere force of chemical affinity cannot be brought out thus with this metal.

5472. *Cadmium; Cadmium; Dil. N. Acid.* Was at 0°. Moved A and it became the least degree Pos. for the time. Moved B and there was a Positive effect barely sensible. Heated A and it became Negative 20° or more—it evolved hydrogen and continued Neg., but gradually falling in force. Cooled A and it became Positive 4° or 5°. Then moved it and it became a little Neg., but went back to Positive 5°. Moved B and it became a little more Negative. Warmed B till it evolved hydrogen and at last boiled, and it became more Negative to 16°; cooled it and it fell to Neg. 6°.

5473. So the effect of heat is to make Cadmium somewhat negative to cold cadmium, and it does this much more than moving does. These effects are probably due principally to the quick production of a saturated solution soon being formed round the Cadmium, i.e. to the acid there being very quickly exhausted and perhaps even a sub salt solution produced. The going back as it cooled might be effected by the gradual removal of this investing solution by the acid around.

5474. Where such metals as Zinc, Tin, Cadmium, etc. are concerned, must remember the affinities are very strong and the effects consequent upon them soon produced. Not likely to get out the effects of heat upon chemical affinity here so well, because even when cold that affinity acts powerfully and instantly on the surrounding acid, etc.

5475. *Zinc; Zinc; dil. N. A.* (5396). On immersion, B was first Pos. rather strongly; then A became Pos. to 28°. Moving B made B more Neg. Moving A made A a little less Pos. So effect of motion was alike in the two cases of A and B. Heating A made it less Pos. down to 10°. Heating B made it more Neg. up to 33°. So the effect of heat is the same for the two and the same as motion. Now moving A and B did the same as before. It seems curious that removing the exhausted film should in these cases make the metal less Positive or more negative, especially as it is not the case only with the piece that has previously been in the Negative state ( ), but with that (as A) which had been previously *Positive*. In reference to this point, should remember that the zinc may have evolved hydrogen, and that if a hydrogenated atmosphere or envelope of solution be around the metals, then moving them might have this striking effect (5468).

5476. Like the Cadmium, this metal has too powerful an affinity for effects of heat on chemical affinity to come out separately in this way.

5477. Now went to compound cases of metals, still in the same dilute Nitric acid.

5478. *Silver; Lead; dil. N. A.* The lead is Pos. to the silver 40°—but deflection falls fast. Moving the lead did nothing. Moving the silver made it more Neg. (5468). Again moving the lead made it a very little more Positive—moving the silver made it much more Negative—so we evidently got rid of an obstruction by moving the silver—when moving the lead there was scarcely a sensible effect produce[d]. This was a very striking case of the reaction back of the silver which had been Neg. to the current, and the removal of that reaction by changing the solution round it.

5479. All being quiet and the lead Pos. 23°, it was heated up to boiling; it became a little more Positive, but not more than such motion might do; the motion of the needle was hardly sensible until the liquid was boiling. Cooling the Lead made very little difference; it was doubtful. Heating the silver made it far more negative and just as the motion would have done.

5480. *Silver; Silver; dil. N. Acid* (5387). Took silver and silver to compare the effect with the silver of the last experiment. There was a little oscillation and then settled at 0°. Heated A and it became very slightly Negative. Cooled A; it made no change. Heated B; it made no change. Moved A: no change—moved B: no change.

5481. It is clear therefore that, in the silver and lead experiment, the silver became surrounded by something, not through its own action, but the action of the current—and on being moved out of this, it allowed the lead to exert a proportionately greater Positive power.

5482. Now tried copper as a much less powerful excitor than Lead.

5483. *Silver; Copper; dil. N.A.* (5400). Copper a little Pos.; settles at Pos. 3°. Moved copper, nothing—moved silver, not sensible effect. Heated silver and it became Neg. to 17°, increasing by 14° in that respect—cooled it and it fell again—heated the copper, no effect—heated the silver again, and again it became Negative and more than before. As the copper had not been cooled, I thought this might be the cause—heated therefore both silver and copper and the Negative deflection was the greatest. So though heating the copper with cold silver does little or nothing, yet heating the copper with hot silver does add to the effect.

5484. It was then left for half an hour; all was cold and at 0°. Then moving the silver did nothing. Heating the Silver made the copper Positive and heating the copper added to the effect.

5485. This effect of Silver is very striking and important. It differs from the case of lead at present in this: that motion here does nothing and there a good deal—and especially in this: that it does not depend apparently upon any *previous current*. It appears like a peculiar effect of heat seen here in silver first, and is remarkable in being negative. It did not appear when cold and hot silver were associated. How will it be when silver is associated with Gold and Platina (5402)?

5486. *Gold; Copper; dil. N.A.* Copper a little Pos. 2°. Heated the Gold and it became Neg. 26°—heated the copper also and there was a still further increase of its Pos. power, but not much. So Gold here was as silver had been before, but in a higher degree. Made the copper hot whilst the Gold was cold, but this did nothing sensibly.

5487. *Platina and Copper; dil. N. Acid.* Copper was more Pos. to Platina than it had been to Gold. Stood at 8°; after a time moved the Platina and this made the copper Pos. 16°. Left all quiet a while and then moved the Platina again, and the copper rose to Pos. 22°. Moving the copper did little if any thing; perhaps added a trace of Positive force to it. This effect is that due to the state produced by the previous current.

The needle had returned to Copper Pos. 15°. Then heated the copper and there was a small sensible increase. Moved the platina and again there was a striking effect up to 48° Pos. for the copper.

Repeated the expt. and had the same results; and after noting them and letting all come to a quiet state, with copper Pos. about 10°, heated the Platina, and the copper immediately became Pos. 40° or 50°—continuing there until the Platina was cooled and then it returned to 5°. Then moving Platina made it Neg. 15° or 20°. Effect of heat on the Platina is very excellent and striking.

5488. *Iron; Zinc; dil. N. Acid.* Zinc very Pos. 90° nearly. In this state could not observe much by the needle, but moving the Iron about in the acid made the Zinc a little more positive, and also moving the Zinc about made it (the Zinc) a little more positive. Here the Iron appears to get rid of an investing portion of the fluid (by the motion) which, through the force of the current, had raised the Pos. force of the iron a little (5468).

5489. *Iron; Cadmium; dil. N. Acid.* Cadmium very Pos.—at 80° —fell a little. Moving the Iron brought up the cadmium again, and this is the same effect as before.

5490. But on heating the Iron, the Cadmium was lowered in its force, becoming less Positive—on cooling the Iron the cadmium rose a little, and it was seen by the colour that Iron had been dissolved. On moving the iron the cadmium rose to its first force nearly.

5491. Now here the two effects of heat, namely the moving effect on the solution and the increase of chemical affinity, appeared as if opposed to each other in the outset and were nearly neutralized, but that at warmest temperature the chemical effect was strongest. Appears to me to be a good case of change of chemical affinity produced by heat, standing out from the other effects and shewing its correspondant influence in affecting the current.

5492. *Cadmium; Tin; dil. N. Acid.* Cadmium Pos. 65° steady. Moved first one, then the other; not much if any effect. Heated the Tin—the cadmium became a little more Positive—cooled the tin—heated the cadmium, still very little effect—no use to me either way.

5493. *Cadmium; Zinc; dil. N. A.* Zinc Pos. 80°. Moved cadmium —no important change—moved zinc and it became a little less positive—heated the zinc, which made a very small difference. No effects for me here. Must have a still weaker acid if I want them to be clearly set forth—but have not time for that research now.

5494. The following are a series of similar experiments made with dilute Sulphuric acid, the same as that used before (5369).

5495. *Gold; Gold; dilute S.A.* There was a deflection and B was Pos. 9°, where it remained a while. Heated A and then B became more Pos. and then fell to 0°. Cooled A: it became a little neg. and then fell to 0°. Heated B: it became the least degree Pos. and then fell to 0°—cooled B: no change—moved A and B: there was the least possible change—nothing. The first effect was I think due to something which, adhering to B, at first rendered it Pos. The effect on heating A was the consequence of the motion of the fluid following upon a current in which A was Neg. After that, Gold shewed very little if any effect, and so it appears that this metal does nothing of itself and that no sensible thermo effect is produced by it.

5496. *Silver; Silver; dil. S.A.* (5377). No deflection—at 0°—motion of A or B made an almost insensible disturbance—heated A: no effect—cooled it: no effect—heated B: no effect—cooled B: no effect.

5497. *Copper; Copper; dil. S.A.* (5378). A little motion and A rested Pos. about 6°—heated B and the needle went back about 8°, B becoming Pos. about 2°—cooled B and it became negative up to 3°—heated A: there was very little change—that was unsteady and I could scarcely say that the heated became clearly the most Positive piece.

5498. *Tin; Tin; dil. S.A.* (5382). Motion and A Pos., but falling to 5°. Moved B and it decreased in Neg. state, needle settling to A Pos. 1°. Moved A: it rose up to Pos. 5° and then sank a little. Heated A: it became more Pos. up to 16° and continued there whilst the heat continued (nearly boiling)—moved B (A being hot) and that a little counteracted A—cooled A: its pos. effect went down to 0°—moved A, which did very little, but caused a trace of Pos.—heated B: it became Pos. 19° and continued—cooled B and it went down to 0°.

5499. I think this is very like a *difference of pure chemical* action *effected by heat* and undisturbed by previous currents producing this or that state in the wires.

5500. *Cadmium; Cadmium; dil. S.A.* Alike 0°. Moved them both in turn and the one moved was always a little negative to the other (5472). Heated A: it became a little Neg. to B—fell again—cooled A and it became much more neg. than before, up to 20°, and continued there—moved A, but its state did not cease, though the deflection gradually went back—moved B and it became a trace Neg.—heated B and it became a little Pos.—continued the heat and it did not become *neg.* It would seem that some irregularity had fallen on the wires, for they do not act alike, which of course they ought to do.

5501. *Zinc; Zinc; dil. S.A.* (5383). Action, and settled A Pos. 18°. Heated B: it became more Neg., A being Pos. 38°—cooled B and the needle went to A Pos. 20°—heated A and it became a very little less Pos.—needle nearly stationary—cooled A and it became a little more Positive. The wires here are irregular and unlike, but heat seems to render the wire more negative.

5502. Now went to *different metals* in the *dil. S.Acid.*

5503. *Platina; Gold; Dil. S.A.* Gold is Pos. to Platina in this acid from the first—was 4° and then settled to very little. Moved the Platina—there was no effect. Heated the platina and it became a little Negative, but hardly sensible. Heated the Gold and Platina both, and then the effect was more sensible, the gold becoming for the time Pos. about 8°.

5504. *Platina; Silver; dil. S.A.* (   ). The silver was Pos. to the Platina about 4°. The platina was moved, but it produced scarcely a sensible effect in rendering the silver more Pos. Heated the Platina, and it became Negative to 30° in a very striking and steady manner—on cooling, the effect gradually fell with the temperature—then on moving the platina an effect of the same kind was produced of not more than 4° or so (produced by the state induced by the previous current). Heating the silver, it did not become less positive, returning to negative (for now it is the positive, not the negative metal which makes all the difference), but more so, and this rose up to Pos. 16° or more—then either moving the platina or especially heating it made the silver highly Positive.

5505. The Platina is here to silver as silver had before been to copper (5483), and as Platina had been to Gold (above), etc. It is a remarkable effect of heat, and in the case of Platina and Gold seems to imply a positive force at the Platina surface to help in determining the current when it is heated. Yet Platina and Platina does nothing of the kind; hence the state of tension which the Pos. metal produces seems necessary for the development of the force by heat.

5506. *Platina; Copper; dilute S.A.* The copper was well Pos. to the Platina—sank to Pos. 15°—moved the platina and it rose to 26° or 28°—settled down again—heated the Platina and the copper rose to Pos. 50°—when all quiet fell again—moving the Platina in the hot fluid, copper rose; fell—cooled: force fell—but on moving the platina, rose again—just as before in the cases of dilute N.A. (5487).

5507. *Gold; Copper; Dil. S.A.* Copper Pos. a little 4°. The motion of the Gold or copper produced nothing sensible. Made the Gold hot and the Copper rose to Pos. 20°. Cooled the Gold and it fell again. Copper heated: no effect. Gold moved whilst the copper was hot: no effect—like as in dil. N.A. (5486), and like Platina, though not to the same extent.

5508. *Silver; Copper; Dil. S.A.* Very little effect. Copper Pos. about 1°—moving copper or silver did nothing—heated the copper: did nothing—heated the silver and when acid boiling, the silver became Neg. and continued so at 20°. Cooled the silver and it went to Neg. 2°—moved it: no change—heated the copper: no effect—heated the silver again: it became Neg. as before. On cooling, it went down again.

5509. In the case where Silver and Silver were compared in dil. S.A. (5496), I took out the Silver B and put copper for it. The copper was the least trace Positive and settled at 1°. Moved silver: no effect—heated silver and it became Neg. 14°, shewing this power of silver, when conjoined with metals Pos. to it, which it has not of itself.

5510. *Copper; Tin; dil. S.A.* Tin Pos. 47°. Moving the Tin did not make it more Pos.—but moving the copper made the tin much more Pos.—on standing, needle went back to Pos. 15°. Then made the copper hot: this rendered it Neg. and the Tin rose to Pos. 70°.

Cooled the copper and the needle returned to 30°, Tin being now Pos. about 40°. Now heated the Tin and it became a little more Pos., about 5° more—cooled it and it remained nearly the same—heated the copper again and it immediately became more Neg., making the Tin Pos. 80° or thereabouts. The effect of heating and motion on the copper is the same, to make it more Neg., it having been the Negative metal.

5511. *Iron; Tin; dil. Sulc. Acid.* Not much effect: the Tin was Pos. 7°. On heating the Iron the needle moved 32° and the Iron became Pos. 25°. Cooled the iron and the needle went back 47°, leaving the tin Pos. 22°. Heated the Tin: it rose still higher to 47° —cooled it and it fell to Pos. 12°. Moving the cold Iron made the tin more Pos. up to 30° or more, but it fell fast again; moving the tin did nothing—moving the Iron again made tin Pos. Warming the Iron at first makes it a little more Negative, but after that a little more heat makes it more Positive. Motion and the first effect of warming do the same thing with the Iron—cooling the Iron diminished its positiveness decidedly.

5512. So Iron appears to have an investing opposing film when it has been Neg. a while, and this either heat or motion removes in part and so makes the Tin more Pos. by comparison. But there is also the Pos. effect produced on iron, and also on the tin too by sufficient temperature, and which appears to be due to a true affection of the chemical affinity.

5513. *Iron; Cadmium; dil. S.A.* Cadmium very Pos.—rested at 70°. Moving the iron made the cadmium more Pos.—moving the cadmium made no change—heating the Iron, the cadmium became more Pos. up to 80°. Here observe the effect of the Iron as the Neg. metal. Gas now came off from the Iron, and this kept up a motion and the needle stood at 80°. Heating the cadmium: no change. On cooling the iron there was a little falling, not much, about 4°, and the gas at the iron was still going off—on moving the iron the Pos. effect of the Cadmium rose as before. This was a very striking effect altogether, and was curious to see the iron more Neg. as it evolved more gas, i.e. as it suffered from more chemical action.

5514. *Iron; Zinc; dil. S.A.* Zinc very Pos., 90° nearly. Heated the iron: made zinc sensibly more Pos., i.e. iron rendered more neg. by heat—cooled the iron and this effect did not go off—heated the zinc: no change—cooled it: no change. Here no change after the first, which must have been casual. The forces are in fact too strong to observe well. With a weaker acid probably bring them out.

5515. *Tin; Cadmium; dil. S.A.* Cadmium Pos. about 80°—fell gradually. At 35° moved the tin and the cadmium immediately rose to full force. The tin is very striking in its effect when Negative and moved. Moving the cadmium did little or nothing. Moving the tin, it is very striking every time. Heating the cadmium produced no sensible effects. Heating the tin produced very great effects, like those of motion. Sometimes when the acid boiled at the Cadmium side, it moved that at the Tin side, and then there was a corresponding effect, but it was produced at the tin side only.

5516. *Zinc; Tin; dil. S.A.* Zinc Pos. 45°. Moving the zinc made it a little more Pos. Moving the Tin made the Zinc much more Positive. Moving the Tin: same effect again. Heating the zinc made it somewhat more Pos. and about as much as moving it—on cooling it fell a little. Heating the Tin made it more Negative, just as moving it did. If the acid round the tin was kept boiling, the tin was then most Negative. The effect of the heat here and in the last experiment is, as to the Tin, altogether an effect of motion.

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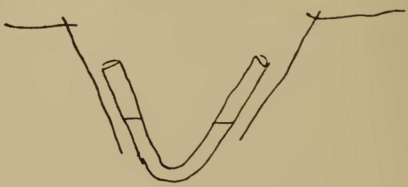
5517*. Now began experiments to ascertain as simply as possible the mere effects of heat on the chemical affinity, excluding as much as I could the effects of previous currents in inducing particular states in the negative wire, and also the effects of a previously investing film of fluid more or less saturated. The metals, well and carefully cleaned each time, were made as before the terminations of the Galvanometer wire. The acid or liquid electrolyte was put into the bent tube. It was then heated to boiling in one leg only, and then the two terminal wires were plunged in simultaneously, and kept moving in the hot and cold fluid during the observation. After noting the deflection, the wires were taken out, cleaned again, and changed, so that that which was hot before should now be cold, and the observation was repeated; and this change of the two

* [5517]



wires A and B was repeated until satisfactory results were obtained. The acid was changed for each new metal or new experiment.

5518. Dilute Sulphuric acid of the strength formerly employed (5369, 5494) was used for the first experiments.

5519. *Platina; Platina; dil. S.A.* The cold Platina was a trace Pos.—changed the wires and then the hot side was a trace Pos.—changed again and the cold side was a trace Pos. The effect is very small and evidently belongs to a particular wire.

5520. *Gold; Gold; dil. S.A.* No effect whichever wire was cold or hot—changed four times. No sensible effect with Gold and Platina in dil. S.A. of a thermo electric kind like that of Seebeck.

5521. *Silver; Silver; dil. S.A.* The first immersion produced an effect, the cold being Pos. But after that, changed four times and produced no effect. Hence hot and cold silver in this dil. S.A. shew no difference.

5522. Must always be aware of possible irregularity at the first immersion. It is hardly possible to have the metals so exactly alike in every circumstance that there shall then be no difference. But the first dip in the acid generally puts that right.

5523. *Copper; Copper; dil. S.A.* The effect not very distinct at first immersion. The hot copper became Pos. for a moment and then rather Neg., continuing so steadily, though the wires were moved the whole time. The same effect was produced when the wires were changed; so that it appears to be a constant and not a casual effect. This metal exhibits a similar effect in N.M. Acid, for which see onwards (5596). The first effect of heat was apparently to exalt the chemical affinity, but that was followed by the formation of an investing coat, and then the cold copper produced most current force, though the hot might perhaps produce most local force.

5524. *Iron; Iron; dil. S.A.* The hot iron always strongly Positive to the cold, to 60° or more. This a *constant* and a *striking* result.

5525. *Tin; Tin; dil. S.A.* The hot tin was always Pos. to the cold, whichever wire was hot, though the two were not quite alike in the degree of Positive at the first. This is a fair result of the increase of effect by heat acting on the chemical force.

5526. *Lead; Lead; dil. S.A.* These wires were somewhat irregular, but continuing the changes for several times, it appeared very clear at last that hot lead was Pos. to the cold, deflecting the needle permanently 20° or more. This result came well out from all the irregularities.

5527. Must have new lead wires—these are too thin and irregular. Had better not clean with sand paper, which drags it into an irregular surface, but with filtering paper, which is quite rough enough.

5528. *Cadmium; Cadmium; dil. S.A.* Both wires acted alike and as follows: the hot cadmium became Pos. to the cold to about 10° at first; it then went down, the motion of the wires in the acid being still continued, until the hot metal became Negative to perhaps 10° and continued there. The first is the increased effect of heat; the second the effect of the investing current.

5529. The very variation amongst these different metals is a still further proof that the effect which produces the current is a chemical effect, not one of contact.

5530. *Zinc; Zinc; dil. S.A.* Requires care till both wires are alike in action—must not take the first results ( ). When both are alike in action, it came out that the hottest is for a moment most Pos., and then it gradually becomes most Negative and up to a degree exceeding the previous Positiveness. This is an effect like that of cadmium, but stronger. The first is the effect of heat increasing action; the second the effect of the investing solution formed at the Positive surface.

5531. Now compared *different metals* and found some most excellent cases of the effects of heat.

5532. *Iron; Tin; dil. S.A.* Hot iron is well Pos. to cold Tin. Hot Tin is still more Pos. to cold Iron. So here an excellent case of the change of the relative electrical state of the two metals by affecting *their chemical affinity*, the contacts remaining the same. Good.

5533. *Iron; Lead; dil. S.A.* Hot iron a little Positive to cold lead. Hot lead much Pos. to cold iron. This a constant and good effect. It shews with two metals, differing in their state at the same temperature, the effect of heat on one either reversing or strengthening the difference. It shews well the combination of the effect of heat with the natural forces. It shews that iron, which is Neg. to Lead, can be made Pos. to it by acting on its chemical forces, though contacts, etc. all remain the same. Good.

5534. *Lead; Tin; Dil. S. A.* Hot tin is a little Pos. to cold Lead, and rather permanently so. Hot lead is more Pos. to cold tin. The effect of heat on the original difference of chemical affinity is very good here. The whole experiment is good evidence.

5535. *Iron; Silver; dil. S. A.* Iron, whether hot or cold, is Pos. to silver.

5536. *Iron; Copper; dil. S. A.* Iron hot or cold is strongly Positive to copper.

5537. *Iron; cadmium; dil. S. A.* Cadmium hot or cold is Positive to Iron.

5538. *Cadmium; Tin; dil. S. A.* Cadmium hot or cold is positive to the Tin.

5539. *Silver; Copper; dil. S. A.* Copper hot or cold is a little Positive to the silver. It is of course understood in these last five cases that the Neg. metal was at the same time cold or hot as the Pos. metal was hot or cold.

5540. I now used another acid, namely the dilute Nitric acid, and that employed was a portion of that which had been used in the former experiments (5385, 5462). These expts. and those will therefore bear comparison as to the effect of the different modes of experimenting with the same substances.

5541. *Platina; Platina; dil. N. A.* No sure sensible effect. There was the least motion, and in the three changes made it was always that *hot Platina* was in a very small degree *Negative* to the cold.

5542. *Gold; Gold; dil. N. A.* Smallest motion—the wires not quite alike in effect—but if there was any thing beyond a small accidental irregularity, it was that the hot Gold was a trace *Negative.*

5543. *Palladium; Palladium; dil. N. A.* Not a clear sensible difference, but if any, it was still that the hot was neg. to the cold.

5544. It is possible that, with these three metals, we may evolve a true thermo-electric effect, undisturbed by any chemical action. If so, then in their case, Metal heated in contact with the Acid becomes Neg.

5545. *Silver; Silver; dil. N. Acid.* There was a small degree of motion in the needle and it was constant after the first immersion of the wires. The hot silver was first Pos. for a moment in a very small degree, and then neutral; as if the heat had thrown by force of chem. action a current into motion, and that had accumulated the resisting state at the Neg. surface, and so all quickly came to rest.

5546. *Copper; Copper; dil. N. A.* Scarcely any motion. The effect was that hot copper was the smallest degree Pos. to the cold.

5547. If there be any thermo effect with the metals and acids, then in these cases of Silver and copper, they and the chemic. effects by heat may be very nearly balanced, and so give such a slight result.

5548. *Iron; Iron; dil. N. A.* Very fine result. The hot iron is always powerfully Pos. to the cold metal, up to 90°. Good.

5549. *Tin; Tin; dil. N. A.* The hot tin is a little, yet fairly *Negative*—it then becomes Positive and continues so in some degree, though the current soon goes down. The wire which has been cold and Negative at last has more of a brown powder that wipes off from it than the Pos.—but on putting one of the wires *not in the circuit* in the cold acid for a while, the same powder was formed on it: the difference depends mainly on temperature. If that which is Neg. or cold in one trial is made the hot in the next, it becomes more Neg. than the Pos. or hot one would do if used immediately again—both wires being of course washed and wiped before using in the second trial.

5550. *Lead; Lead; dil. N. A.* The leads are apparently inactive for a moment, i.e. the needle does not instantly move—and then the hot lead becomes Neg. to the cold and rather continues so, sinking but slowly, though the motion be continued in the acid (as in all these experiments). There is apparently no increase in the force of the chemical affinity, though there is increase in the amount of action at the hot surface, and therefore more local effect and the more rapid production of an exhausted solution there.

5551. *Cadmium; Cadmium; dil. N. A.* After a moment's pauze the hot cadmium became Neg. to the cold; just as above with the lead.

5552. *Zinc; Zinc; dil. N. Acid.* The hot zinc is a little Positive to the cold, and then the effect goes down, as in all these cases nearly; but it did not become Neg. in the time I waited.

5553. On washing and wiping the zincs, that which had been hot gave no soiling powder to the wiping cloth, but that which had been Neg. did give such a powder. The same is the case with Tin and lead and I think with Cadmium.

5554. Now came to *different metals* in the *dilute N. Acid.*

5555. *Iron; Tin; dil. N.A.* Hot iron is Pos. to cold Tin. Hot tin is more Pos. to cold Iron—both are well developed states. If, when the iron is to be plunged in the hot side, the acid is only moderately warm, it seems at first as if the Tin would almost overpower the Iron, so beautifully can the forces be balanced or rendered predominant by heat at will. Very Good result.

5556. *Iron; Lead; dil. N.A.* Iron hot is fairly Pos. to cold Lead. Lead hot is very Pos. to cold Iron. Very beautiful here to see the superposition of the effects of heat on the relative chemical forces at common temperatures.

5557. *Tin; Lead; dil. N.A.* Lead is Pos. to Tin, whether it be hot or cold; but it is far the most Pos. when Lead is hot, shewing the difference induced by heat upon the ordinary and specific chemical affinities of the two metals.

5558. *Iron; Copper; dil. N.A.* Iron hot or cold is Pos. to copper.

5559. *Iron; Palladium; dil. N.A.* Iron both ways Pos. to Palladium.

5560. *Iron; Silver; Dil. N.A.* Iron both ways Pos. to Silver.

5561. *Iron; Cadmium; dil. N.A.* Cadmium both ways Pos. to Iron.

5562. *Iron; Zinc; dil. N.A.* Zinc both ways Pos. to Iron.

5563. *Tin; Cadmium; dil. N.A.* Cadmium Pos. to Tin both ways.

5564. *Cadmium; Zinc; dil. N.A.* Zinc Pos. to Cadmium both ways.

5565. *Silver; Copper; dil. N.A.* Copper is Pos. to silver both ways; but cold copper is more Pos. to hot silver than hot copper to cold silver, judging by the needle.

5566. This curious effect is explained by the effects of heat on the negative metals when they are silver, gold, platina, etc. (5485, 5505), and is a good case to illustrate the great care required in making and comparing these experiments. There is little doubt but that copper with Gold and Platina, and also silver with these metals, would shew the same effect.

5567. I now went through these metals again, using *dilute Muriatic acid* as the exciting electrolyte. The solution used consisted of one measure of a strong solution of pure muriatic acid and 29 measures of water.

5568. *Platina; Platina; dil. M. A.* No sensible effect between hot and cold pieces.

5569. *Gold; Gold; dil. M. A.* The hot gold became very slightly negative; with both wires.

5570. *Palladium; Palladium; dil. M. A.* No sensible effect.

5571. *Silver; Silver; dil. M. A.* The hot silver was the smallest trace Positive; with both wires.

5572. *Copper; Copper; dil. M. A.* Hot copper was strongly Positive to the cold copper—under all the changes. The effect was very Good.

5573. *Iron; Iron; dil. M. A.* Hot Iron very Pos. indeed to the cold Iron. Result very strong and good.

5574. *Lead; Lead; dil. M. A.* Hot Lead very Pos. to the cold lead. Striking result.

5575. *Tin; Tin; dil. M. A.* Hot Tin well Positive to the cold, whichever wire used. Is a good result. There was no dark deposit on the Negative wire in this acid.

5576. *Cadmium; Cadmium; dil. M. A.* Hot cadmium well Pos. to the cold cadmium. *Good result.* No deposit on the Negative wire.

5577. *Zinc; Zinc; dil. M. A.* The hot metal well Positive to the cold metal. *Good.*

5578. So there are six metals at least: Copper, Iron, Lead, Tin, Cadmium and Zinc, which can have their electromotive force in Muriatic acid very beautifully affected by heat acting on the chemical forces.

Now compared different metals in the dil. Mur. acid.

5579. *Iron; Tin; dil. M. A.* Hot Iron is just and fairly Pos. to Tin at the boiling point of the acid—but hot Tin is very Positive to Iron. The superposition of the effect of heat on chemical affinity is very good here.

5580. *Iron; Lead; dil. M. A.* Hot Iron is Pos. to Lead. Hot Lead is Pos. to Iron. Good effect.

5581. *Lead; Tin; dil. M. A.* Hot lead is well Pos. to Tin. Hot Tin is more Pos. to Lead. Excellent.

5581¼. *Lead; Cadmium; dil. M. A.* Cadmium Pos. to Lead both ways.

5581½. *Lead; Zinc; dil. M. A.* Zinc Pos. to Lead both ways.

5582. *Iron; Copper; dil. M. A.* Iron Pos. to copper both ways.

5583. *Iron; Cadmium; dil. M.A.* Cadmium Pos. to Iron both ways.

5584. *Iron; Zinc; dil. M.A.* Zinc Pos. to Iron both ways.

5585. *Tin; Cadmium; dil. M.A.* Cadmium Pos. to Tin both ways.

5586. *Tin; Zinc; dil. M.A.* Zinc Pos. to Tin both ways.

5587. *Lead; Copper; dil. M.A.* Lead Pos. to copper both ways.

5588. *Palladium; Copper; dil. M.A.* Copper Pos. to Palladium both ways.

5588½. *Cadmium; Zinc; dil. M.A.* Zinc Pos. to Cadmium both ways.

5589. Made a few experiments with Gold, Silver, Platina, etc. and a much stronger Muriatic acid, consisting of *one volume* of the strongest pure solution and *one volume of water*.

5590. *Platina; Platina; Strong M.A.* (1 M.A. + 1 W.). The one heated is a trace negative to the cold wire; and that was distinctly so, whichever wire was heated. Is this a pure thermo-electric effect?

5591. *Gold; Gold; Strong M.A.* (1 M.A. + 1 W.). No great difference, only about 2° or 3°, but the wire heated is distinctly negative on its immersion.

5592. *Silver; Silver; Strong M.A.* (1 M.A. + 1 W.). There was very little effect—not more than with the dilute Muriatic acid (5571). The result was of a doubtful nature.

5593. I now added a little nitric acid (not much) to the remaining portion of the strong diluted Mur. acid (5589), so as to make a nitro muriatic acid.

5594. *Platina; Platina; the N.M. Acid.* The hot platina was Negative to the cold Platina and much more than before—perhaps to 10°. There was I think chemical action on the Platina in the hot solution, but not sensible by the colour by candle light.

5595. *Gold; Gold; the N.M. Acid.* The hot gold was strongly Negative to the cold gold—far more than before: 50° or 60° in fact. Yet chemical action was going on well and strongly at the hot gold, so as quickly to render the solution of the gold evident, both by the change on the surface of the wire and the colour of the solution. This is a very remarkable action. The effect may depend upon all the chemical forces, or nearly all, being balanced locally at the hot side, the dynamic force being exerted mainly at the cold side, where it is not so directly converted into local action. It is known that heat alone would affect the constitution and state of the Nitro muriatic acid, setting chlorine free; and that free chlorine, acting on the Gold, would not produce dynamic force, though it would form an investing coat of exhausted solution to the hot gold (5806).

5596. *Copper; Copper; the N. M. Acid.* Looked for the action of copper in this same acid, to illustrate the action on gold. At first the hot copper was pos. to the cold copper; then it became covered with a dark crust, and then it was, though hot, strongly Negative; it gave off a little gas and it dissolved away in the acid, forming a green solution and continuing negative. This Negative state is either a direct or secondary effect of the chemical actions concerned (5523). It may be like that supposed above with Gold. But it is very curious and will help in one way or another to illustrate the chemical affinities concerned.

5597. The Gold experiment has probably a direct relation to Mr Groves' experiment of Gold in N. acid and M. acid in a voltaic form.

5598. *Platina; Copper; the N. M. Acid.* The copper was alway[s] Pos. to the Platina, whichever was hot or cold.

5599. *Silver; Copper; the N. M. Acid.* The copper was always Pos. to the silver—whether hot or cold.

5600. Again made it *Copper; Copper; the N. M. A.*, and again the hot and active copper was Negative to the cold and Passive copper.

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5601. Made a few further experiments on Nitro muriatic acid (5593). The acid consisted of 4 *vols. strong solution of pure Mur. acid;* 1 *vol. pure strong Nitric acid; and* 4 *vols. of distilled water.*

5602. *Iron; Iron; N. M. Acid.* The hot iron is always Pos. to the cold. There is very much action at the hot side, whilst at the cold side it is not sensible during the experiment to the eye. Still, there is an enormous proportion of local action and not much dynamic force. The deflection is far most powerful at first moment of immersion, though chemical action at the hot side rises greatly a moment or two afterwards.

5603. *Iron; Copper; N. M. Acid.* The Iron, whether cold or hot, was very Pos. to the copper. Yet the sensible and powerful chemical action was at the hot side, whether that wire Iron or copper. Here the needful distinction between local and current action very striking.

5604. *Copper; Palladium; N. M. Acid.* Copper either hot or cold is Pos. to the Palladium. Yet the abundant chemical action is in both cases at the hot side. The cold copper is far more Pos. to the hot Palladium when the chemical action is well on at the latter than before—as if the solution formed around the Palladium had helped much to reduce its state, and so render the copper relatively more Positive.

5605. These kinds of experiments must in some way help to illustrate and elucidate local action in ordinary chemical cases, for one would think that, as the action is going on so violently, some parts of the Palladium must be negative not only to the copper, but also to parts or particles of the Palladium itself.

5606. Proceeded to add a few more experiments to those already made with *Strong Pure Nitric acid* (5410), using the same acid as before.

5607. *Platina; Platina; Strong N. A.* The hot a trace Negative, whichever wire used: perhaps 2°. The first immersion was not good, so repeated until I obtained a constant result. Is this a pure *thermo-electric* effect? It is negative (5799).

5608. *Gold; Gold; Strong N. Acid.* The hot Gold is Negative to the cold gold and more than in the dilute N. A. (5542), but much as the Platina in Strong N. A. (5607). It is an effect which quickly goes off; the first swing of the needle is rather good, but the second swing in the same direction is not sensibly more on one side, than the return swing is on the other, of 0°.

5609. *Palladium; Palladium; Strong N. A.* Very strong chemical action on the hot Palladium, but not a sensible one for the short time of the experiment on the cold side. Still the hot Palladium was strongly *Negative* to the cold, and far more so than in the corresponding cases of Gold and Platina. The chemical action is the cause of this, by investing the Palladium with partially exhausted acid, etc. The action at the hot metal is apparently altogether local.

5610. It is not at all unlikely that with such a body as nitric acid, the forces which at low temperatures may take a dynamic condition should, when heat comes in to break by violent action the previous relation of them, then become nearly all local. There are many bodies which, scarcely acting at low temperatures on Nitric acid, break forth into a violent and a *new form* of action by the aid of a little heat.

5611. *Silver; Silver; Strong N. A.* The action was very irregular, whichever wire was hot. Sometimes the hot and sometimes the cold wire was Positive strongly, the changes taking place suddenly. There was strong action at both wires, but no doubt the strongest at the hot side. The real forces seemed nearly balanced, but the variations in the condition of the acid and of the investing solution seemed to produce the changes.

5612. The case was the same when both silvers were cold in strong N. Acid (5448).

5613. *Iron; Iron; Strong N. Acid.* At the first moment the cold Iron is strongly Pos. to the hot; but in that moment a change takes place and the hot iron becomes permanently Pos. to the cold. There is probably action at both surfaces at the first moment, and indeed red fumes appear at the hot side for an instant; but then the effects fall and there is no continuing sensible chemical action at *either* side.

5614. *Copper; Copper; Strong N. A.* Very powerful chemical action at the hot side and but very little comparitively at the cold side. Yet the hot copper is but very little Positive to the cold, and I am hardly sure it is so at all. The action is very nearly all local.

5615. *Platina; copper; Strong N. A.* The hot copper exhibits much chemical action and is well Pos. to the Platina, but not more I think than cold copper would be.

5616. I must pursue *Nitric Acid* and *Nitro muriatic acid* by themselves hereafter. Nitric acid is probably a bad electrolyte in itself as compared to Muriatic acid, etc. etc. It probably acts, when used, principally by disposing of the hydrogen, etc. etc. at the cathode, and so facilitates the production of current force.

5617. Now wrought with a solution of *caustic potash* (5424). It was the same solution as that used before, but in the present series the solution was made hot on one side, and then the metals simultaneously plunged into the hot and cold parts and moved about whilst the observation was made.

5618. *Platina; Platina; Caustic Potash.* Neglected the first immersion. Afterwards the hot platina was the least possible trace Pos. to the cold platina—but only for the moment of immersion (5425).

5619. *Gold; Gold; Potash sol.* The least trace of motion—doubtful which way. At one time the hot gold seemed a minute degree Positive.

5620. *Palladium; Palladium; Potash.* No sensible difference between the hot and cold.

5621. *Silver; Silver; Potash.* Difference scarcely sensible: if any thing, the hot was a trace Pos. to the cold (5426).

5622. *Iron; Iron; Potash.* The hot was Positive for the first moment, but the effect was almost instantly over—though renewed upon every repetition of the experiment (5427).

5623. *Copper; Copper; Potash.* The hot copper was well Positive to the cold, and rather continued. The hot metal tarnishes in the solution quickly; the cold does not. A Good case (5428).

5624. *Lead; Lead; Potash.* The hot lead was well and steadily Pos. to the cold—with both wires. Good result. At the first moment of immersion there is a little, very little, jerk at the needle, as if the hot lead would be *Neg.* for an instant (5429).

5625. *Tin; Tin; Potash.* The hot tin very and constantly Pos. to the cold (5431). Good.

5626. *Cadmium; Cadmium; Potash.* The hot cadmium is Pos. to the cold—not very strong, but well. *Good.*

5627. *Zinc; Zinc; Potash.* The two wires were not quite alike in degree, but both were Positive in turn when made *hot*—only one was rather stronger than the other. Is a good result in itself as to effect of heat (5432).

5628. Thus *Copper*, *lead*, *tin*, *cadmium* and *zinc* could be made Positive to themselves only by difference of temperature and could invert the relations of the two pieces. Now proceeded to compare *different metals* to ascertain whether they could be so far affected in this manner as to pass by each other.

5629. *Lead; Tin; Sol. Potash.* Tin cold fairly and well Positive. Tin hot very Positive. So here, though the Tin was always

Positive; yet the difference in degree illustrates the action of heat.

5630. *Lead; Cadmium; Sol. Potash.* Cold cadmium fairly Positive to Lead, but hot Cadmium is very Pos. to lead. Same difference as above.

5631. In the rest the difference is not so striking.

5632. *Silver; Copper; Potash.* Copper, whether hot or cold, is moderately Pos. to silver.

5633. *Copper; Lead; Potash.* Lead, whether hot or cold, strongly Pos.

5634. *Copper; Tin; Potash.* Tin, hot or cold, strongly Positive.

5635. *Copper; Zinc; Potash.* Zinc, hot or cold, strongly Positive. The copper was oxidized and tarnished in these three experiments, as well as when it was Pos. to silver or to itself.

5636. *Iron; Tin; Potash.* Tin, hot or cold, was strongly Positive.

5637. *Iron; Lead; Potash.* Lead, hot or cold, strongly Positive.

5638. *Tin; Cadmium; Potash.* Tin, hot or cold, is Positive.

5639. *Tin; Zinc; Potash.* Zinc, hot or cold, is strongly Positive.

5640. *Zinc; Cadmium; Potash.* Zinc, hot or cold, is strongly Positive.

5641. Thus Potash does not shew those strong conversions of the states of the metals that the acids do, by heat: but such a variation is in full harmony with the variations of chemical affinity. The cases rather help to strengthen the reference to chemical forces than to effects of mere contact.

5642. Now proceeded to use a dilute solution of the sulphuret of Potash as the electrolyte (5433). It was made of 1 vol. of the former strong solution (5268) and 15 vols. of water. One side of the solution in the tube was first heated, and then the metals plunged in and moved about as in all the recent experiments (5517).

5643. When this solution is heated, it darkens very much in colour, and from a pale yellow becomes a deep brown.

5644. *Platina; Platina; dil. Sulrt. Potash.* Hot or cold, no difference.

5645. *Gold; Gold; dil. Sulrt. Potash.* Once the hot was a little Neg., but I do not believe it was a pure result. The general result is that there is no difference. The needle moves the least Possible.

5646. *Palladium; Palladium; dil. Sulrt. Potash.* No change: is like Platina and Gold.

5647. *Iron; Iron; dil. Sulrt. Potash.* The hot Iron is well Positive to the cold with both wires. The Negative and cold wire keeps quite clean, but from the hot iron a dark sulphuret separates into the solution, discolouring it; and also another portion of the same dark sulphuret washes and wipes off from the iron as a black powder (5795). Good.

5648. *Silver; Silver; dil. Sulrt. Potash.* The hot silver is a little Pos. to the cold, fairly but not much. The hot is acted upon far the most—but the cold is a little acted upon also.

5649. *Copper; Copper; dil. Sulrt. Potash.* The hot copper well Pos. to the cold on first immersion, but the effect quickly falls. Both are strongly acted on by the sulphuret, but the hot most. Good result.

5650. *Tin; Tin; dil. Sulrt. Potash.* There was very little motion of the needle, but the hot tin becomes a little *Negative* to the cold. The wires require to be cleaned very carefully each time by scraping or sandpaper, etc., or else the investing sulphuret interferes much. This precaution is the more necessary with tin and such metals as give films of sulphuret not sensible from their colour to the eye.

5651. *Lead; Lead; dil. Sulrt. Potash.* The hot was with both wires fairly Negative to the cold. Yet the hot was much the most acted upon. There was much local action and in consequence a deterioration of the electrolyte at that surface of the metal.

5652. *Cadmium; Cadmium; dil. Sulrt. Potash.* No sensible change at the first moment—but afterwards the hot cadmium became perhaps a very little *Negative*.

5653. *Zinc; Zinc; dil. Sulrt. Potash.* No action at the first moment—then the hot zinc became quickly but gradually and at last strongly Neg., up to 70° or 80°. This was a constant effect. Both zincs keep bright and I believe the sulphuret dissolves off (   ). That is probably a reason why the hot becomes so highly Negative, the investing fluid becoming more altered here w[h]ere the actions can go on.

5654. These cases of the hot metals becoming Neg. are very interesting, and fully accord with theory of chemical action.

Now proceeded to use *different metals* together.

5655. *Platina; Iron; sol. sulrt. Pot. dil.* With cold Iron and hot Platina, the Platina was clearly Pos. a little. With hot iron and cold platina, the iron was a little Pos. to the Platina—not much: not so much as when hot iron was opposed to cold iron (5622). The Platina appears to have a quelling or opposing effect.

5656. *Cadmium; Zinc; dil. Sulrt. Potash.* Cold zinc is moderately Pos. to hot Cadmium. Cold cadmium is also moderately Pos. to hot zinc. The first moment is quiet, and then this action comes on; it depends upon the negative condition of zinc and cadmium, which is due to investing solution, and is increased by heat (5626, 5627). Still it is a fair inversion of state with two different metals and the sulphuret of potassa.

5657. *Silver; Lead; Sulrt. potash.* Silver hot is a little Pos. to Lead. Silver cold is more, and well Pos. to lead. The difference by heat evident.

5658. *Silver; Tin; sol. sulrt. potash.* Hot tin is Pos. at the first moment to silver and then becomes neutral or even a little Neg., and the silver is but little tarnished. Cold tin is very slightly Pos. to hot silver, and now the silver is much tarnished.

5659. *Silver; cadmium; sol. sulrt. potash.* Hot cadmium well Pos. to cold silver—action instantly over—silver not tarnished sensibly. Cold cadmium is Pos. to silver more than when hot, and the silver is now much tarnished. Hot silver receives but little Pos. power. Hot cadmium becomes quickly neg.—hence satisfactory cause of the result.

5660. *Copper; Zinc; sol. sulrt. Potash.* Copper hot or cold is Pos. to zinc cold or hot. Is most Pos. when copper cold and zinc hot —because of negative state coming on with zinc.

5661. *Iron; zinc; sol. sulrt. pot.* Hot zinc is Pos. to Iron, but cold zinc is much more so, from falling of hot zinc in power.

5662. *Tin; Zinc; sol. sulrt. potash.* There is no action at first—but in a few moments cold Tin is a little Pos. to hot zinc and cold zinc is more and fairly pos. to hot tin. A case of inversion, like that of Cadmium and zinc (5656).

5663. *Tin; Lead; sol. sulrt. potash.* Hot tin a little pos. to cold lead—cold tin more pos. to hot lead—similar effect of the investing solution.

5664. *Zinc; Lead; sol. sulrt. potash.* Zinc hot is slightly Pos. to cold Lead and soon falls. Zinc cold is very Pos. to lead. Same kind of result as before.

5665. *Tin; Cadmium; sol. sulrt. potash.* Hot cadmium very little Pos.—cold cadmium more Pos.—effects very moderate.

5666. *Silver; Zinc; sol. sulrt. potash.* Cold zinc very pos. to silver. Hot zinc is Pos. at first to silver moderately and then in a moment or two it becomes Neg. to the silver, from the effect of the investing coat, etc.

5667. *Silver; Copper; sol. Sulrt. pot.* Copper hot or cold is Pos. to silver cold or hot.

5668. *Copper; Lead; sol. sulrt. pot.* Copper hot or cold is Pos. to Lead cold or hot.

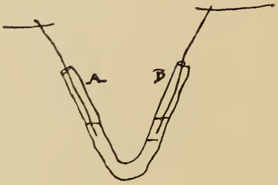
5669. *Copper; Cadmium; sol. sulrt. pot.* At first moments neutral and then copper, whether hot or cold, becomes Pos. to the cadmium, rising gradually: as if the cadmium had equal power whilst forming its investing sulphuret and then, it gradually diminishing in action, the copper gained the superiority.

5670. *Copper; Tin; sol. sulrt. pot.* Copper hot or cold is Positive feebly to the tin cold or hot.

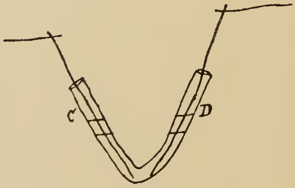
5671. *Lead; Cadmium; sol. sulrt. pot.* Cold cadmium is well pos. to Lead—goes down quickly—hot cadmium is also well Pos. to lead.

5672. *Gold; Platina; sol. sulrt. pot.* No effect hot or cold.

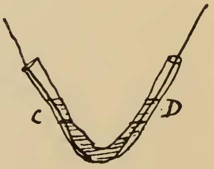
5673. Wished to compare the effect of the same metal and of different metals in the same acid, strong and dilute. The following are two modes used. Into a syphon tube was put some pure strong acid, and then a few drops of water were added at the B side. So when the wires were introduced into A or B, the effect of the strong or weak acid upon them could be compared.



5674. Another mode was this. A similar tube had some strong acid put into it; then the two wires were introduced and afterwards a drop or two of water was put at the top of the acid in each leg. Then either wire could be retained in the strong acid, whilst the other was raised with its end into the dilute acid, and then the former could be in turn raised and the latter depressed.



5675. First experimented with strong pure nitric acid and platina wires, to see what results, independant of the acting metals, as copper, etc., would appear. Put nitric acid into the tube, inserted the platina wires, and then when all was quiet at the Galvanometer, put a little water into both legs of the bent tube. There was then



much effect on the needle, and the least motion of the tube helped to produce changes, though when all was quiet the needle was at 0° and at rest.

5676. The general effects were as follows. If the wire in C were raised into the weak acid, it became well Pos.; if the wire were held there quietly, the state went down; if it were moved in the weak acid, the wire became Pos.; if, being quiet in the weak acid, it were lowered into the stronger acid beneath, it became Pos. If the wire in C were left quiet in the strong acid and that in D were moved, it shewed exactly the same effects, becomg. Pos. in turn.

5677. If one was taken out, washed, wiped and reintroduced, it became Pos. the moment it touched the dilute acid.

5678. These effects were very considerable in this tube and important. None of them were permanent, so that they are not effects of contact. In 10′ or 15′, on making the same movements, the effects were much less than before. I believe all to depend upon the act of combination of the stronger acid and water.

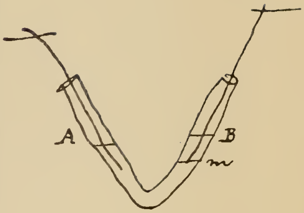
5679. I used gold wires instead of platina and found similar effects, but weak. I emptied the tube and put fresh acid and water, so as to have the stronger effects of mixing, and now found the phenomena more powerful by far, though perhaps not quite so powerful as with platina.

5680. I then put very dilute Nitric acid into the bent tube, placed the wire C of platina or gold (5675) in its place, dipped wire D into strong nitric acid and plunged it into the other leg D of the tube. There was immediately a strong deflection of the needle, the wire in the weak acid being Pos. and that in the strong acid Negative. Then emptying the tube, it was filled with strong N. Acid; one wire was put in its place, the other dipped in water and then immersed wet in the acid; immediately there was deflection; the wire last put in was Pos. and that in the strong Acid Neg.

5681. This is quite in accordance as to direction, etc. with the former results. So when with one wire in the strong acid and the other in the weak, and all at 0°, if the one in the weak acid be depressed into the strong acid, it becomes Pos.

5682. The effect appears due to the act of combination, which in some way determines a current such as would result from the wire in the strong acid being negative and that in the weak acid Positive.

5683. When the tube was arranged thus, with water or dilute acid in one limb only, then on dipping platina wires in about the $\frac{1}{3}$ of an inch or so, the effects were by no means so strong (for the length of bad conductor was then much greater between the ends of the wires); and by observing their amount, they could easily be distinguished from those dependant upon chemical effects which metals other than Platina or gold might produce. This arrangement of tube with one dilute extremity I will call No. 1, and the other arrangement with 2 dilute extremities I will call No. 2.



5684. *Platina; Platina; in strong and dilute N.A.* in No. 1. Not much effect; that due to mixture of fluids.

5685. *Gold; Gold; and N. Acid* in No. 1. Scarcely sensible effect.

5686. *Palladium; Palladium; and Do.* As Platina and Gold. So these three produced no sensible chemical effects by strong and dilute N. Acid.

5687. *Silver; Silver; in strong and dilute N.A.* in No. 1. At first the dilute side was very Positive to the strong side—but after some time the needle jumped round and the strong acid side becomes very Pos. to the weak side and generally keeps there. Silver is very powerful and changeable in Nitric acid (see 5448, 5449); but these very changes seem to me to be against the theory of contact and for chemical action. It is the free acid which, with the metal, determines the current—not the bodies produced in the solution; they only retard it. But if the free acid acted by contact, then surely the stronger acid would act more powerfully than the weak at the outset, when all is fair; yet the weak acts best.

5688. Whatever circumstance in fact tends to make the fluid a more powerful chemical agent and a better electrolyte (that being a pure chemical relation, not one of contact), favours the production of a determinate current and the positive state.

5689. *Copper; Copper; and N.A.* in tube No. 1. The end in the weak acid is powerfully Pos. to that in the strong acid. By using tube No. 2, can hold the needle powerfully in either direction at will, simply by bringing the end of the wire to be Pos. into the weak acid, and the other into the strong acid (5674). The effect was most excellent.

5690. *Lead; Lead; and Nitric acid.* The wire in the weak acid was Pos. to that in the strong acid and powerfully so. The alternation of state, when using tube No. 2, was excellent; and the whole experiment, as with copper, is a fine experiment.

5691. *Iron; Iron; and Nitric acid strong and dilute.* That wire in the weak acid is Pos. to the other. The alternations in tube 2 are beautiful, as with copper and lead.

5692. *Tin; Tin; strong and weak N.A.* The tin in the dilute acid is Pos. to that in the strong. Very violent action comes on here in the strong acid, or between it and the water, which mixes all up, and so the alternations are not so well observed with this metal as the former three.

5693. *Cadmium; Cadmium; Strong and weak N.A.* Cadmium in the diluted acid is Pos. to that in the strong acid. Powerful action and evolution of gas quickly mixes all up together.

5694. *Zinc; Zinc; Strong and weak N.A.* Same as Tin and cadmium; that in weak acid was Pos. to that in the strong acid.

5695. Now by way of comparing different metals in strong and weak N. A., I tried *Silver*, *copper*, *Iron* and *lead* against each other, for from the effects with the same metal, I thought that any one of these might be made Positive or Negative to *all* the others. They were tried in tube No. 1. The result was that

5696. *Copper* in the dilute acid was Pos. to Silver, Iron and lead in the strong acid and that strongly; that

5697. *Iron* in the dilute acid was strongly positive to silver, Copper and Lead in the strong acid; that

5698. *Lead* in the dilute acid was strongly positive to Silver, copper and Iron in the strong acid; and that

5699. *Silver* in the dilute acid was Positive to Iron and Lead—and almost to copper, i.e. it was negative, but only feebly so, and almost in a balanced state in comparison with the forces developed on the previous occasion.

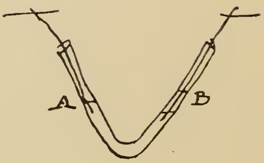
5700. Thus with the exception of silver Pos. to copper, any one of these metals may be made Positive or negative to the other by mere dilution of the acid.

5701. On making similar experiments with Tin, it when in the weak N. acid was strongly Pos. to Copper, lead, Iron and Silver in the strong acid—and when in the strong acid it was strongly Negative to copper, lead and Iron in the weak acid and a little so to silver even. So that these five metals may be made Pos. or Neg. to each other by mere dilution of the N.A. and no change of contact, making 10 Pos. and 10 Neg. changes, with the exception of silver Pos. to copper.

5702. *Cadmium* in the weak acid side is Very Pos., as might be expected, to Silver, copper, lead, Iron and Tin in the strong acid. Cadmium in the Strong Acid is Negative to lead; is neutral or perhaps Neg. to tin; is slightly Pos. to silver and copper and Pos. to Iron when these are in the weak acid.

5703. *Zinc* in the weak acid is Very Pos. to Silver, copper, lead, Iron, tin and cadmium, but in the strong acid is well Neg. to lead, iron, tin and cadmium, but a little pos. to Silver and copper.

5704. So also Zinc, Cadmium, Tin and Lead, and likewise Zinc, tin, Iron and lead, are groups of four metals each which, by means of dilution of the nitric acid only, can be made Pos. or negative to each other.



5705. Proceeded to try different metals, the electrolyte being Sulphuric acid, which was strong in one leg of the tube No. 1 and diluted in the other (5673). As a commencing experiment I diluted some acid by mixing 49 by weight of strong oil of vitriol and 9 of water, to give an acid with about 2 proportions of water; but on putting this acid into the tube on the stronger acid at B, and using Iron wires in A and B, I did not find that this degree of dilution made much difference. Nothing like so much as when a little water were put on B and slightly stirred upon the acid there, and left so as to give strata of different degrees of dilution. Therefore in the succeeding experiments used the latter mode.

5706. *Platina; Platina; Strong and Weak S.A.* That in the dilute acid is a little Pos. to the other. See Nc. acid and Platina (5684).

5707. *Gold; Gold; Strong and weak S.A.* Scarcely any change.

5708. *Palladium; Palladium; Do. Acid.* The weak is a little Pos., as gold or Platina might be expected to be.

5709. *Silver; Silver; strong and weak S.A.* On first immersion, the dilute acid side was Pos., but the current fell to 0°—then after trials gave almost insensible changes—could not say there was a decided difference.

5710. *Copper; Copper; strong and weak S.A.* That in the dilute acid is weakly Pos. to the other. By using tube No. 2 with dilute acid at the top in both legs, I could alternate the state of the wires and make either Positive in the weaker acid; but the effect is by no means so strong as that with the nitric acid (5689).

5711. *Iron; Iron; Strong and dilute S.A.* Whichever was in the dilute acid was Pos. to the other. Could alternate the state of the wires well in tube No. 2 (5674).

5712. *Lead; Lead; Strong and dilute S.A.* Rather irregular, but the one in the strong acid is the most Positive in almost every case. This is a good contrast of the different effects of the action of water as contrasted with those we might expect from effects of contact. The chemical action is here as strong in the stronger acid as in the dilute, and stronger indeed, judging from the sulphate formed.

5713. *Tin; Tin; Strong and dilute S.A.* The strongest acid here determines the Positive side and that constantly. Can alternate the states here and make either wire Pos. at pleasure by making it the one in the strong acid. This is in very striking contrast with Iron or copper.

5714. *Cadmium; Cadmium; Strong and dilute S.A.* Unsteady—no great difference. Sometimes the wire in the strongest and sometimes that in the weakest acid is Positive.

5715. *Zinc; Zinc; Strong and dilute S.A.* At the commencement the Strong acid was Pos. I alternated the ends into strong and weak acid (5674), and for a time the strongest acid side was still the Positive, but free effervescence of gas in the dilute acid came on by degrees and then the weak acid side was the Positive side.

5716. Made a few comparisons of different metals.

5717. *Iron; Cadmium; Strong and weak S.A.* Cadmium in the weak or strong acid was Pos. to the Iron.

5718. *Iron; Silver; Strong and weak S.A.* Iron in strong acid is a little Pos. to Silver in dilute acid. Iron in dilute acid is full Pos. to silver in the strong acid.

5719. *Iron; Copper; Strong and weak S.A.* Iron in strong or weak acid was Pos. to the copper.

5720. *Iron; Tin; Strong and weak S.A.* Tin in strong or weak acid is Positive to the Iron.

5721. *Tin; Silver; strong and weak S.A.* Tin in strong or weak acid is Positive to the silver.

5722. *Tin; Copper; Strong and weak S.A.* Tin in strong or weak acid is Positive to the copper.

5723. *Tin; Cadmium; Strong or weak S.A.* Cadmium in strong or weak acid is Positive to the Tin.

5724. So this acid is in beautiful chemical contrast with the Nitric acid, for none of the metals can be made to pass the others in their Positive and Negative relation by the contrast of strong and weak acid; and whilst copper and Iron are positive in the weaker acid, other metals, as lead and tin, are Positive in the stronger acid.

5725. Experimented with Muriatic acid. It was hardly necessary, for as the strongest acid solution is still much diluted, i.e. contains much water, it was probable that it would always act as a watered acid. But still, ran through the 9 or 10 metals. Used the strongest solution of pure Muriatic acid I could obtain, and employing tube No. 1, diluted on the top of the acid in the leg B and so experimented by dipping the clean wires quickly in and moving them as before (5517).

5726. *Platina; Platina; Strong and weak M.A.* Scarcely any change. If any, the strong acid side is the least Pos.

5727. *Gold; Gold; Strong and weak M.A.* Insensible.

5728. *Palladium; Palladium; Do. Acid.* If any effect, it is that the strongest acid is the smallest trace Pos.

5729. *Silver; Silver; Strong and weak M.A.* Silver in strongest acid is most Pos.—about 30°.

5730. *Copper; Copper; Strong and weak M.A.* Copper in strongest acid is very Pos.

5731. *Iron; Iron; Strong and weak M.A.* The strong acid side is for a moment the most Pos.; then quickly after the weak acid side is Pos. and continues so.

5732. *Lead; Lead; Strong and weak M.A.* The strong acid side is Pos.

5733. *Tin; Tin; Strong and weak M.A.* The strong acid side is Pos.

5734. *Cadmium; Cadmium; Strong and weak M. A.* Strong acid side is Pos.

5735. *Zinc; Zinc; Strong and weak M. A.* Strong acid side is Pos. at the first immersion—the action is quickly so violent as to prevent continued observation.

5736. Thus this solution of Muriatic acid is in contrast to both the Nitric and the sulphuric. The strongest is always the most Pos.

5737. Wished to know what *Potash* would do by dilution. So made a *very strong solution of good potassa fuza* and employed it.

5738. *Platina; Platina; Strong and weak potash.* The wire in the strong solution was clearly a trace Pos. to the other. Is this an effect of mixtion? If so, it is in the reverse direction to that of Nitric acid mixtion (5682). Or is it chemical effect? I took care to make all of the same temperature.

5739. Must remember that such a solution is a pretty good conductor of electricity and therefore shews feeble currents.

5740. *Gold; Gold; Strong and weak Potash.* Gold in the strong is clearly Pos. a little to that in the weak. More than in Platina case.

5741. *Palladium; Palladium; Strong and weak Potash.* Same, and about as Gold.

5742. *Silver; Silver; Do. Potash.* Same, and but little more than Gold.

5743. *Copper; Copper; Do. Potash.* Strong solution side was Positive 30° or 35°. Could alternate the ends so as to make either Positive or Negative.

5744. *Iron; Iron; Do. Potash.* Strong solution Pos. about 12° or 15°—and that with either wire.

5745. *Lead; Lead; Do. Potash.* Strong solution was very Pos. to the weak side; 80° or more. Could alternate the states of the ends.

5746. *Tin; Tin; Do. Potash.* Strong sol. side very Pos. to the weak. Could as with lead alternate the state of the ends.

5747. *Cadmium; Cadmium; Do. Potash.* Strong solution very Pos. to the weak; as lead, etc., could easily alternate the states. The cadmium quickly changed the colour of the strong solution, making it appear (by candle light) of rather a dark colour.

5748. *Zinc; Zinc; Do. Potash.* Strong solution very Positive. Could easily alternate the states of the ends.

5749. *Zinc* was Pos. to tin, cadmium and lead, whether in the weak or the strong alkali. *Tin* is Pos. to cadmium, whether in weak or strong alkali. *Cadmium* is Pos. to lead both ways; but most when in the strong alkali. So there are no inversions of the order of the metals here.

5750. Potash is like M. A. and contrasted with N. A. and S. A. in several respects.

5751. I endeavoured to select two metals which, being in one order in a cold acid solution, should be so differently affected by heat as to have that order reversed in the same solution when hot. The following were the trials and results.

5752. *Tin* and *Iron* in *cold dilute S. A.* (5369). The tin was slightly Positive to the Iron. In the *same acid heated to boiling* the tin was perhaps mostly Positive, but the Iron was sometimes pos. on the first immersion and very distinctly so.

5753. *Tin* and *Lead* in *cold dil. S. A.* (5369). The tin was Positive a little when both metals were perfectly clean on their immersion (this cleansing requires much care). In hot dilute sulc. acid heated to boiling, the Lead was a little Pos. to the tin.

5754. So here there was a change in the order of the two metals by the simple action of heat alike on both, but the change was slight, and it would require to be very sure about the first effect of the two in the cold acid, as it is not in the same order as in dilute N. Acid.

5755. Tried to find a pair of metals which should be reversed in order by the action of strong or dilute acid upon them. For as Iron in weak S. acid is *Pos.* to that in strong S. A., and as lead or tin in weak S. A. is *Neg.* to that in strong S. A., it did not seem impossible to find a pair which should, when both were in strong acid, have A Pos. and B Neg., and when both were in weak acid, should have A Neg. and B Pos.; which could hardly consist with the theory of contact.

5756. When *Iron and Silver* were put into the *same strong Nitric* acid, for the first instant the Iron was Pos., but immediately after, the silver became Pos. strongly and continued so. When they were put into the same weak nitric acid, then the Silver was Negative. This therefore was at last a strong contrast.

5757. When Iron and copper were in Strong Nitric acid, at the first moment the iron was Pos., and then the copper permanently so. In the weak Nitric acid the copper was permanently Neg. So here the same sort of contrast.

5758. *Silver and lead* in Strong and weak N.A. The lead was Positive in both cases.

5759. Then with Strong and weak Sulphuric acid.

5760. *Tin and Iron* in strong and weak Sulphuric acid. The tin Positive in both cases.

5761. *Tin and Cadmium* Do. The cadmium Pos. both ways.

5762. *Tin and Zinc* Do. The Zinc Pos. both ways.

5763. *Iron and lead* Do. The Lead Pos. both ways. There were differences in degree but not in kind. Generally the Pos. metal was most Pos. in the Strongest acid, but that was not the case with Tin and Zinc and sulphuric acid.

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